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University Licensing: Harnessing or Tarnishing Faculty Research?

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Executive Summary

The central issue we consider is whether university patent licensing, afforded by the Bayh-Dole Act, has diverted universities away from their basic research mission. The act, passed in 1980, was intended to stimulate the transfer of federally funded research to industry. While statistics on licensing activity suggest that it has served this purpose, they have also fueled debates as to whether licensing has also led faculty to abandon basic research agendas. We show that, quite to the contrary, when realistic complexities of the research environment are taken into account, it is just as natural to expect basic research productivity to have been enhanced by licensing. Our evidence on disclosure, funding, and publications (their nature and impact) of faculty in 11 universities lends credence to the notion that, rather than diverting faculty research, licensing is part of a flurry of activities that can be associated with fundamental discoveries from fairly basic research.

I. Introduction

Since 1980, universities have been able to patent and exclusively license results of federally funded research under the auspices of the Bayh-Dole Act. Since then, organized university-industry technology transfer has increased substantially. The number of technology transfer offices increased more than eightfold, and activities reported to the Association of University Technology Managers (AUTM, various years) by these offices show remarkable growth. The 119 U.S. nonprofit respondents to the AUTM annual survey who responded in both 1996 and 2007 reported that inventions disclosed by faculty between those dates almost doubled from an average of 67.1 per institution to 131.1.[1] New patent applications increased from an average of 23.2 per institution to 77.6 (growth of 234%). The number of license and option agreements executed rose 81.1% from an average of 19 to 34.4. Licensing income

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more than tripled in current dollars from $550.7 million to $1,715.6 million. License income as a percentage of total research expenditures rose from 2.25% to 4.31%.

This dramatic growth in university patent licensing is alarming to some but touted by others as evidence of the increasing role of universities in the U.S. national innovation system. As such, it has fueled the policy debates over the merits of intellectual property rights for university inventions (Krimsky 2003; Greenburg 2007). These debates have been subject to considerable exaggeration and hyperbole. To wit, the enabling Bayh-Dole Act has been reported as "perhaps the most inspired piece of legislation to be enacted in America over the past half-century" (*Economist* 2002, 3) and as having put "the profit motive directly into the heart of academic life," driving faculty away from curiosity-driven basic research (Washburn 2005, 70).

Bayh-Dole grew out of concerns that, while the United States led other nations in basic research, it lagged in the transfer of research to industry. The act was intended to provide incentives for industry to adopt and develop federally funded inventions. Today, however, there are concerns about the basic research enterprise itself, given multiyear reductions in federal funding for academic research (National Science Board 2008a). Thus, if licensing has diverted faculty from basic research, it is considered to be a serious matter. The problem is that the impact of financial incentives on research is not as straightforward as one might think, depending critically on the nature of the research process as well as on faculty motivations. In this paper, we argue that the view espoused above—of basic research as distinct from research with commercial potential—is much too simple, and perhaps misleading, to frame the policy debate.

To see this, consider research into protein folding. A large number of neurological disorders (e.g., Alzheimer's, Huntington's, and Parkinson's diseases) are now thought to be associated with problems in the folding process, the protein misalignments that arise and the strange protein structures that subsequently arise (particularly in the brain). The examination of this phenomenon has the potential to provide many types of research projects—some quite basic, such as the biophysics of the folding process, and others more applied, such as looking for ways to disentangle the proteins or limit their entanglement to halt the progression of particular diseases. Both types of projects are often conducted within the same lab, and both have intellectual and commercial application. For example, in 2003 a well-known molecular biologist, Sue Lindquist, published a paper in *Science* on the molecular pathways underlying normal function of the alpha-synuclein protein and the consequences of its misfolding (Outeiro and Lindquist 2003). In the same issue, Lindquist and others published a more applied paper on the implications of misfolding for neurodegeneration in diseases such as Huntington's and Parkinson's, and a paired patent application (U.S. 7,452,670) was filed on methods of identifying agents that diminish cellular toxicity associated with alpha-synuclein polypeptide of Parkinson's disease in yeast (Willingham et al. 2003). Lindquist is also one of the scientific founders of a company, FoldRx, that focuses on developing small molecule therapeutics for treatment of diseases caused by misfolding. Thus, research in this lab and, arguably, many others (Murray 2002; Jensen and Murray 2005) is in sharp contrast to the "either-or" view of basic and commercially applicable research as distinct.

In this paper, we examine the impact of financial incentives associated with licensing through the lens of a synthetic framework that allows us to compare and contrast this more complex research environment, in which basic publishable research has commercial potential, with the "either-or" view of such projects as distinct. Our analysis takes into account the fact that academic researchers are motivated by a "taste" for scientific research in addition to financial rewards. This, along with our models of the research production process (or, in economic terms, the research production function) provides several key insights—some quite intuitive but others more subtle and surprising.

First, regarding motivation, the licensing statistics cited earlier may well be simply the result of faculty being more willing to disclose their research, not only through publications but also by licensing and patenting (Thursby and Thursby 2002). That is, research that is dual purpose (in the sense that it has both intellectual and commercial value) is now disseminated in multiple venues beyond traditional publications (Murray 2002; Jensen and Murray 2005; Murray and Stern 2006). This point was quite prominent in an interview we conducted with Lindquist. In what she called the "blooming of knowledge" in her field, she noted that basic research has progressed so far in terms of understanding how cells work that applications have become more readily apparent. Further, while the framers of Bayh-Dole may have understood the need for exclusive patent rights for industrial development, early on scientists did not. Over time, however, they have come to understand that unless they patent and license their research, it will never be used. She emphasized that these activities are necessary for "her life's work to make a difference."

Second, simulations of our models for various production functions show that, while on average licensing draws research toward projects with higher commercial potential, it also increases overall research effort, which in most cases leads to an increase in the amount of basic research conducted. This result seems natural in cases where basic and applied research are complements in the sense that applied and basic effort conducted by the same researcher (or in the same lab) allows for spillovers across projects. Somewhat surprisingly, however, it holds even in the absence of such cross-project benefits. The result that basic research tends to increase comes from two things: (i) faculty in our model respond to licensing by spending more time in research per se, and (ii) both types of research are published as well as licensed—something seen in the Lindquist example. The extreme case, in which basic research necessarily suffers from licensing, arises only when the applied effort associated with licensing is not publishable.

Thus the impact of licensing on research is ultimately an empirical issue, and there is a growing body of empirical research that has focused on a related topic, the relationship between faculty publication and patenting. Two results stand out from this work. First, only a minority of faculty in top U.S. universities are involved in patenting (Stephan et al. 2007), and second, for those faculty who patent and publish, there appears to be a positive relation between them. In fact, in sharp contrast to critics' fears of diversion, Azoulay, Ding, and Stuart (2007, 2009) find evidence to suggest the converse in the life sciences where patent applications appear to follow flurries of publication. In this paper, we present evidence on the publication and invention disclosure records of faculty at 11 major universities and how disclosure is linked to sponsored research, publications, and citations. Our results echo these earlier findings; as well, they support the contention that licensing may have increased basic effort.

II. Faculty Research Agendas

To understand faculty research agendas it is important to recognize that university faculty value academic freedom (Stern 2004; Aghion, Dewatripont, and Stein 2008). Rather than negotiating with their employers over the focus of their research and its dissemination, they are free to choose research projects (Gans, Murray, and Stern 2008). Although university administrators can influence research by the reward structures they put in place, the determination of research agendas is the purview of faculty themselves. Except for the general requirement in U.S. employment contracts that faculty disclose inventions with commercial potential to the university, how they disseminate their work is also their choice. Moreover, faculty contracts specify a teaching load and a limit on outside consulting, which leaves the faculty member to determine their effort and the type of research they conduct.

In this section, we present a framework that allows us to relate license incentives to research agendas. We draw heavily on Thursby, Thursby, and Gupta-Mukherjee (2007), which presents a formal model of faculty research over the life cycle in the context of university licensing.

A. Research Motivation

One of the keys to understanding the projects faculty choose is their motivation for research. Faculty drawn into scientific disciplines are generally thought to have a taste for solving basic research puzzles, getting satisfaction simply by working on them as well as being the "first" to solve them (Merton 1957; Hagstrom 1965; Kuhn 1970). In this context it is easy to see why the impact of financial incentives associated with licensing is not straightforward. If research with license potential can only be done by reducing effort on curiosity-driven projects, there is a trade-off between the expected increase in income and job satisfaction. Further complicating the issue, faculty reputations as well as academic salaries are highly dependent on the scientific merit of their research. Thus faculty research decisions depend on the importance they attach to basic, puzzle-solving research and its associated reputation relative to the potential monetary gains in terms of academic and license income. For many faculty, the anticipated monetary gains from licensing may not be sufficient to warrant the distraction from curiosity-driven projects.

Recognize, however, that curiosity-driven and licensable projects may not be distinct. This is easily seen in the context of Stokes's (1997) characterization of research projects as to whether they are motivated by the desire for general understanding or oriented toward solving particular problems (such as new materials, devices, products, etc.). Table 1 shows Stokes's quadrant model of scientific research. The vertical axis shows whether research is curiosity driven, and the horizontal axis shows whether research is use oriented. For some types of research, these are useful distinctions. For example, Bohr's study of atomic structure belongs in the upper-left-hand quadrant, with very different motivation than research in Edison's Menlo Park lab to develop profitable electric lighting (lower-right-hand quadrant). In the context of the current debate, if a faculty member were to switch from projects in Bohr's quadrant to Edison's in order to earn license income, they would clearly have been diverted by license incentives. However, much of Pasteur's research that

Table 1
Quadrant Model of Scientific Research

	Use Oriented	
	No	Yes
Curiosity driven understanding:		
Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
No		Pure applied research (Edison)

Note: Adapted from Stokes (1997, 73).

provided the foundations of modern microbiology grew out of his applied research to improve fermentation of beet juice or pasteurization of milk. Thus, as Stokes emphasizes, the common practice of defining basic and applied research in terms of motivation is not particularly meaningful.[2]

B. Research Production Functions

It is also important to understand the relationship between inputs to basic and applied research and their respective outputs—that is, the research production functions. In general, such functions show the amount of output that is produced when research effort is combined with other inputs, such as the stock of knowledge and equipment. Despite the shortcomings mentioned above, we adopt the convention of referring to basic research as the investigation of fundamental aspects of phenomena and applied research as directed toward specific applications. For some production functions, basic and applied research may be complementary. More applied projects may provide insights (and tools) of use for the lab's basic projects and vice versa, a phenomenon linked to Mansfield's finding that faculty ties with industry were a major source of ideas for their academic work (Mansfield 1995). Finally, both types of projects can have both scientific and commercial value, as in Pasteur's quadrant.

In terms of the Lindquist example, the paper on the molecular pathways underlying protein function would be considered basic and the paper on the implications of misfolding for neurogeneration in Parkinson's diseases would be applied by our definition. Both projects have resulted in publications in top journals, and both have clear commercial potential although perhaps on a different time scale—the biophysics of folding might lead to new biomarkers, analytic methods, or diagnostics, while molecules to block misfolding pathways might be patentable drugs.

Since both projects involve the function of the alpha-synuclein protein, there are likely complementarities across the projects. As emphasized in our interview with Dr. Lindquist, even though the papers on applications for particular diseases are in some sense more applied, they still deal with basic biophysics.

In the current context, the outputs of interest are publications and license activity. For research in Pasteur's quadrant, both outputs are functions of the amount of effort in basic and applied projects as well as the stock of knowledge (the state of science). If basic and applied projects are complementary, then increasing effort in either project, at the margin, increases productivity of effort in the other project. The formal models of Thursby et al. (2007) incorporate both this notion of spillovers in the production of publications and more independent projects without spillovers. They also incorporate complementarity of basic and applied effort for licensing and loosely capture the notion that inventions licensed require further development before they are commercially useful (Jensen and Thursby 2001; Thursby et al. 2002). Another critical element of our specification of production in Pasteur's quadrant is that applied research projects result in publication as well as licenses. This is meant to capture the notion that while research licensed by firms contributes to the firm's knowledge base, it contributes to general public knowledge only with publication.

In contrast, in the "either-or" view of basic and applied research, the two types of effort lead to different types of outputs. Consistent with research in Bohr's quadrant aimed solely at scientific knowledge, our formal models allow basic research to affect license output only through their impact on the stock of knowledge. A formal representation of research in Edison's quadrant, where the sole aim of effort is to produce results of use to companies, would allow applied effort to produce licenses but not publications. Thus, applied effort in such models does not add to the stock of knowledge.

C. Research over the Life Cycle

Thursby et al. (2007) build several models of faculty research over their career that incorporate the multiple faculty goals and production structures discussed above. In the models considered, a faculty member faces a fixed teaching load and chooses the amount of time to devote to research (which can be either basic or applied) and the amount of time to take as leisure (i.e., not working on income-generating projects). This faculty member gets satisfaction from puzzle solving and from a reputation for publications and earns a salary from the university. To examine the impact of financial incentives associated with licensing, we solve the model with and without the possibility of additional income from a share of license revenue. This allows us to examine the effect of licensing on the research mix, as well as the total amount of time working, throughout the career life cycle.

We simulated the outcomes of these models for a large number of parameter values. In our simulations, with or without licensing and regardless of the relationship between basic and applied research, faculty devote more time to research early in their careers. This is because research is an investment in future productivity, and the value of this investment falls toward the end of the career. Their taste for puzzle solving leads faculty to conduct more research toward the end of the life cycle than they might otherwise conduct if the only rewards are monetary (see also Levin and Stephan 1991). The potential for license income has several effects. In all of the simulations, the ratio of basic to applied effort is lower with licensing. Perhaps the most important point of the analysis, however, is that licensing does not necessarily compromise either the amount of basic research or total research effort. Indeed, in the majority of simulations, both basic and total research efforts increase because less time is spent on non-income-generating activity. Interestingly, this result holds whether or not applied and basic efforts are complementary. The cases in which basic and total research effort are lower with licensing are ones in which applied research is not publishable or when license income is extremely high.

Thus the impact of licensing activity on the direction and amount of research is essentially an empirical issue. If licensable research is not publishable or if faculty regularly "hit the jackpot," then it is quite likely that basic research is compromised. But to the extent that faculty have a taste for basic work there may be no impact, and if their basic and applied efforts are related in some way (and both publishable), the research enterprise may benefit. The effect of these incentives surely varies among faculty, so the interesting question is what has happened overall.

III. What Is the Evidence?

There is a growing body of empirical work focused on the impact of commercial activity on research. Because research effort is unobservable, the bulk of this literature has focused on the relationship between measures of research outputs (such as invention disclosures or patents) to publications and citations to publications. Broadly speaking, this work has failed to show detrimental effects in terms of these output measures.

Consistent with the view that faculty may not alter their behavior, several investigators have found that the majority of faculty they study have avoided commercial activity. In Stephan et al.'s (2007) study of full-time faculty who answered the 1995 Survey of Doctorate Recipients, only 9% of the sample made patent applications in the prior 5 years. As we discuss below, only a minority of faculty in top U.S. universities have engaged in the licensing process.

Studies that relate patenting and publishing tend to find that they go hand in hand (Murray 2002; Stephan et al. 2007; Fabrizio and DiMinin 2008).[3] In terms of publication impact, the results are mixed. Agrawal and Henderson (2002) find a positive relationship between patenting and publication citations for faculty in two engineering departments at MIT. Fabrizio and DiMinin find that after a faculty member's first patent there is little impact, but that as faculty repeatedly patent their publication citations fall. These studies, however, do not directly address the extent to which the nature of research is affected by commercial activity.

Azoulay et al. (2007) examine the life-cycle patenting behavior of 3,884 scientists in biomedical fields from 1967 to 1999 and find that patenting peaks in mid-career years. They develop a measure of the latent patentability of each scientist's research by relating areas identified by publication titles to a measure of the extent to which other scientists working in these areas patented their discoveries. Using hazard-rate and logistic models, they find that patent applications follow flurries of publication, holding constant latent patentability. This suggests that, rather than diminishing or shifting in response to returns from patentable research, research creates opportunities for patenting. From the perspective of an individual researcher, then, academic patenting and entrepreneurship might be a natural consequence of moving along a particular research trajectory rather than a diversion away from more basic research.

Azoulay et al. (2009) employ the same database to examine related questions in terms of the quality and content of publication. They find that scientists who patent are more prolific publishers than those who do not, controlling for other characteristics. Interestingly, however, the quality of publications, as measured by the impact factor of the journal of publication in a given year, as well as the proportion of publications in which the scientist appears first or last in the authorship list, is not significantly different between scientists who patent and those who do not. Goldfarb, Marschke, and Smith (2008) find a similar relation between inventive activity as measured by invention disclosures and the quantity and quality of publications for Stanford electrical engineers.

In a series of papers (Thursby and Thursby 2007a, 2007b, 2008), we examined a longitudinal database on research inputs and outputs of faculty at 11 major research universities over a period of 17 years. In the next section, we provide summary statistics from that database. In Thursby and Thursby (2008) we consider econometric models using these data. The models explain sponsored research funding, publications, and citations controlling for, among other things, such factors as the age of the faculty, their major field of research (biological sciences, engineering, or physical sciences), gender, whether they have tenure, the year of their PhD, and a measure of the academic quality of their department. In all models we include measures of disclosure activity. One finding of note is that faculty who never disclose are, in general, less productive than those who do. Similar to Fabrizio and DiMinin (2008) and Azoulay et al. (2007, 2009) we find that faculty who disclose are more productive in a year following their disclosure.

IV. Who Discloses? A Profile of Faculty Research

In this section, we provide a more detailed look at the nature of research inputs and outputs for faculty in the longitudinal database mentioned above. The data cover most of the 1980s and all of the 1990s. This period is particularly important since it coincides with a time of relatively low levels of licensing and culminates in a period of relatively intense licensing activity.

We focus on invention disclosures, rather than licenses or patents, as our measure of faculty engagement in the license process. A disclosure reflects only the opinion of the faculty researcher on the commercial potential of an invention. It does not reflect any judgment by the university technology transfer office (TTO) on the invention's commercial potential or patentability, as would patent applications. Nor does it reflect the opinion of patent examiners or the market, as would patents awarded or licenses executed. In the case of patents awarded, novelty and usefulness would influence the outcome, and in the case of licenses executed, both the TTO ability and the market's opinion would be reflected. Thus, we argue that disclosures are the preferable measure of faculty participation.

While all universities in the sample require their employees to file invention disclosures, this is hardly enforceable. Faculty may not disclose for a variety of reasons. In some cases they may not realize the commercial potential of their ideas, but often faculty do not disclose inventions because they are unwilling to risk delaying publication during the patent and license process.[4] Faculty who specialize in basic research may not disclose because they are unwilling to spend time on the applied research and development that is often needed for businesses to be interested in licensing university inventions (Thursby and Thursby 2002; Jensen, Thursby, and Thursby 2003). While a disclosure signals a willingness to be involved with licensing, it need not indicate that the research was motivated by the desire to license. As discussed in Section II, basic curiosity-driven research can often lead to commercially applicable results. In their interviews with MIT faculty, Agrawal and Henderson (2002) found that most conducted research with the primary goal of publishing.

Thus a fundamental part of our data is the record of when and how often faculty file invention disclosures. We divide faculty into three samples. In the first we include only faculty who never disclose in any year they are in our sample.[5] The other two samples include faculty with at least one disclosure, and those faculty observations are divided into periods of disclosure activity and periods of nondisclosure activity. This allows us to characterize which faculty become involved in licensing activity as well as the nature of their research in periods of license disclosure.

To characterize faculty research profiles, we use publication counts along with a number of measures of the type of research conducted. One can think of the number of publications in any period as a measure of the success of the overall research effort. Measures of the type of research (basic or applied) include the number of citations each publication receives as well as a classification developed by Narin, Pinski, and Gee (1976) as to how basic are the journals in which the faculty member publishes. Both measures incorporate the notion that the results of basic research are more likely to be highly cited than those from applied research. Finally, we have data on the amounts of federal and industry-sponsored research funding received annually by each faculty member. This gives us a window into how finances affect research outputs, but it can also be thought of as an indicator of the type of research since federally sponsored research is generally for more basic questions than is industry-sponsored research funding.

A. Data

Our data are the research, demographic, and disclosure profiles of all faculty scientists and engineers in PhD-granting departments at 11 major universities: California Institute of Technology, Cornell University, Georgia

Institute of Technology, Harvard University, Massachusetts Institute of Technology, Purdue University, Stanford University, Texas A&M University, University of Pennsylvania, University of Utah, and University of Wisconsin at Madison. Each is a major research university, and each has faculty actively engaged in licensing; all compare favorably to the top 50 universities in terms of total research expenditures, licenses executed, patents awarded, and invention disclosures as reported in the 2007 AUTM survey. For example, the average research expenditure for our sample in 2007 is $656 million, compared to an average of $555 million for the top 50 research universities. The sample average number of invention disclosures in 2007 is 325, compared to 226 for the top 50 universities.

Faculty are those on the list of science and engineering faculty in PhD-granting departments provided in the 1995 National Research Council (NRC 1995) report. Faculty not listed in PhD-granting departments are excluded; importantly, medical school faculty are excluded unless they also hold appointments in PhD-granting departments. Departments are excluded if one could not reasonably expect disclosure activity (for example, we exclude astronomy).

The technology transfer office of each university in our sample supplied the names of disclosing faculty as well as dates of disclosure. Four universities provided disclosure information for 1983–99, and the others provided information from 1983 to 1996 or from 1987 to 1999.[6] Matching these files with the NRC list provides a sample composed of multiple years of disclosure activity for faculty in residence in 1993. Not only are faculty in non-PhD-granting departments excluded, but we cannot include those who join a university after 1993 or who left a university before 1993. For years other than 1993 we checked to ensure that each faculty member was in residence. There are 4,988 faculty and 60,905 observations in the sample, where an observation consists of a person in some year; on average, faculty are in the sample for approximately 12 years.

As noted, faculty are divided into three samples based on their disclosure history. In the first we include only faculty who never disclose in any year they are in our sample. In our figures we refer to this as the "Never Disc" sample. In the other samples are faculty who disclose at least once. In one of these we include faculty in a 3-year "window" around the time of a disclosure that includes the year of the disclosure as well as the year before and the year after; in our figures we refer to this sample as the "Disc Period" group.[7] In the final sample we include faculty who disclose in at least one year but who do not disclose in the current year, the year before, or the year after. This sample is referred to as the "Non-Disc Period" sample. Thus, for the latter two samples we include faculty who disclose at least once and we separate observations into periods of disclosure and nondisclosure activity.

The disclosure data are supplemented with data from Thomson Institute for Scientific Information (ISI) on the number of publications by year for each of the faculty as well as the total citations those publications receive through 2003. For example, if a faculty member had three publications in 1995, then our publication measure is three and the citation measure is the total citations those three publications had received through 2003. While the citation data are truncated, we have at least 4 years of citation information for every publication.

An additional measure of the nature of research is a mapping of each journal publication into Narin et al.'s (1976) classification of the "basicness" of journals. This classification characterizes journals by their influence on other research, and it has been updated regularly. They argue that basic journals are cited more by applied journals than vice versa, so that journals are considered to be basic if they tend to be heavily cited by other journals. For example, if journal B is heavily cited by journal A, but A does not tend to be cited by B, then B is said to be a more basic journal than A. Advantages of the Narin classification are not only its measure of influence but also ease of extending the measure to a large number of journals and articles. The ratings are on a 4-point scale, and we classify as basic only publications in the top basic category that covers about 62% of all ranked journal publications in our sample. About a third of all publications could be rated, but we found no systematic change over time in the number of publications that could be rated. If none of a professor's publications are rated in some year, or if they do not publish in some year, then those observations are dropped. This leaves 14,401 person/year observations for which we can measure how basic the research is. The measure of basic publications we use is determined by finding the fraction of rated publications that are in the most basic category of the Narin classification. It is then assumed that this same fraction of basic work extends to all of the researcher's publications in that year. Thus the calculated number of basic citations is the fraction of rated publications that are basic multiplied times the total number of publications.

Another indicator of the type of research conducted by a faculty member is the type of research funding received, where it is natural to expect federal funding to support more basic research than industry-sponsored funding. For eight of the universities (Purdue, MIT, Stanford, Wisconsin, Georgia Tech, Cornell, Pennsylvania, and Texas A&M) the office of sponsored research provided information on sponsored research funds from federal and industry sources. The number of faculty at these eight universities is 4,240.

B. How Common Is Disclosure?

For each person in the sample we know whether she disclosed in each year she was on the faculty and, if so, how many times she disclosed in that year. The sample has 5,133 person/year observations (this is 8.4% of the sample) in which there is at least one invention disclosure. Taking into account multiple disclosures in a year, the total number of disclosures is 9,240.

Consistent with the view that faculty may not alter their behavior is the finding in our data that the number of faculty who ever disclose is remarkably low. Sixty-three and a half percent of the 4,988 faculty in the sample never disclosed an invention, and another 14.6% disclosed in only a single year. Only 109 (2.2%) disclosed in eight or more of the years they were in the sample. When a faculty member discloses in some year it is typically a single event. For 3,304 of the 5,133 person/year disclosure observations (64.4%) there was a single disclosure. In 1,040 of the disclosure years (20.3%) the faculty member had disclosed twice. Forty-five of the disclosure years are cases of 10 or more disclosures by a faculty member in a single year. The distribution of disclosures varies substantially by university, from a low of 4.41% of faculty disclosing to a high of 17.7%.

The yearly percentage of faculty who disclose at least once in the year rises from 2.7% of the faculty in 1983 to around 10%–11% by the mid-nineties, where it appears to have leveled off. The average number of disclosures per faculty member per year rises from about 0.04 to about 0.25. The upward trend in the average number of disclosures is more marked than the rise in the fraction of faculty who disclose in each year, further emphasizing that disclosure activity is concentrated in a minority of the faculty.

Interestingly, publication among the faculty in our sample is also highly concentrated in a minority of faculty. For the entire sample, the average number of publications per year is 3.84. Almost 31% of the person/year observations are ones in which there are no publications, and for another 15.2% there is only a single publication. In only 11.2% of the sample are there 10 or more publications in a year.

C. How Productive Are Disclosers?

Are the disclosers the more productive faculty, as in the case of Stephan et al.'s (2007) study of patenting? Figure 1 gives the average annual

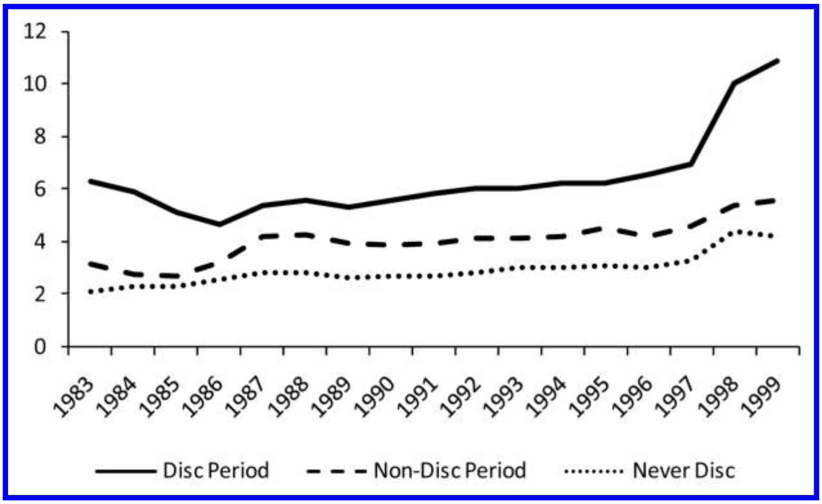

Fig. 1. Average publications. All annual comparisons are statistically significantly different at a 5% level.

number of publications for faculty in the three subsamples. Two results are striking. First, those who disclose are on average more productive in terms of numbers of publications than those who never disclose. Second, those who disclose publish more in the years surrounding disclosure than in nondisclosure years. Thus, as in Azoulay et al. (2007) and Thursby and Thursby (2008), there is a flurry of publication activity surrounding disclosure.

Another way to look at productivity is in terms of faculty ability to attract research funding. Data on federal and industry funding by researcher and year are available for only eight of the 11 universities. This sample includes 4,240 researchers and 51,951 person/year observations. Thirty-two percent did not have federal money in any year in which they are in the sample, and almost 63% never received industry funding. For all person/years, 54.8% are observations for which there is neither source of funding. In 9.4% of the sample both types of funding are observed.

Figure 2 gives average annual federal funding (in real terms) for the three samples.[8] The funding pattern is clear. Faculty who never disclose have, on average, substantially lower annual levels of federal funding, and the highest levels of funding are for those who are in a disclosure window (Disc Period). In almost every case the differences by year and across samples are statistically significantly different from zero. Industry funding follows a similar pattern. For the sake of economy we do not present the details. We do note one distinct difference. For faculty in a disclosure window, industry funding rises dramatically in the late

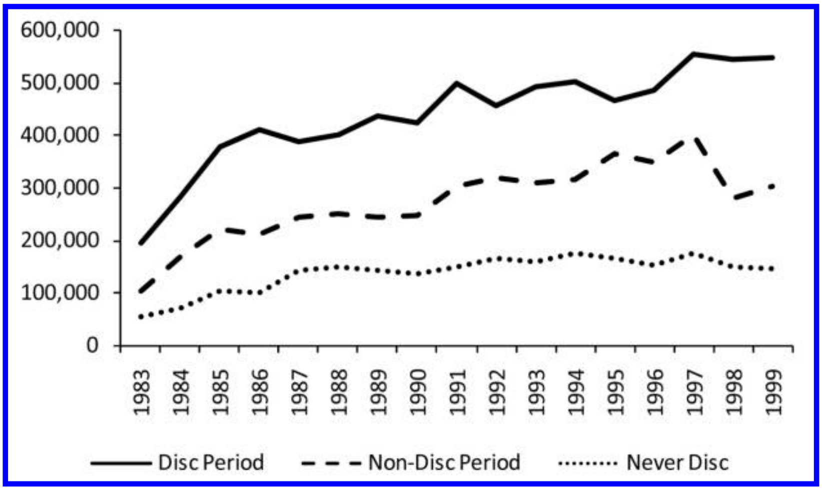

Fig. 2. Average real federal funding. Differences between Never Disc and Disc Period are significant at a 5% level for 16 years. Differences between Never Disc and Non-Disc Period are significant at a 5% level for 16 years. Differences between Disc Period and Non-Disc Period are significant at a 5% level for 11 years; two other years are significant at a 10% level.

1980s, then falls dramatically in the early 1990s before again increasing in the late 1990s. This "bubble" in the middle years is driven by engineering and, to a lesser extent, by physical sciences.

Not only are disclosers different from nondisclosers in levels of funding, but they are also different in the growth of funding. From the late 1980s on, the never-disclose sample has virtually no growth in funding. In contrast, funding for the other two samples is increasing over the period (except for Disc Period industry funding from 1992 to 1995). Furthermore, the increased growth for both types of funding is consistent with the econometric analyses in Jensen, Thursby, and Thursby (2008) and Thursby and Thursby (2008), which suggest that federal funding and industry funding to universities are complementary.

Federal and industry funding can also be considered as measures of the type of research conducted. Except for mission agencies, we typically think of federal agencies as providing funding for more fundamental research and industrial funding as more targeted. Interpreted in this way, the funding picture does not suggest diversion of research. In the next section, we look more directly at this question.

D. The Nature of Faculty Research

In this section, we examine two citation-based measures of the nature of faculty research. The first is citations per publication, and the second is our Narin-based measure of the number of basic publications. While the latter has the disadvantage of fewer observations, the advantage is that it allows us to look at both the number of basic publications and the portion of research that is basic. According to our characterization of basic and applied research in Section II, the total publication counts for disclosers shown in figure 1 may reflect higher productivity in both basic and applied research (although we would expect disclosers to have a higher ratio of applied to basic publication).

Recall that the measure of citations is the number of citations to a work in a particular year received through 2003. For example, if Joe the professor has five publications in 1995, then the citation number for Joe in 1995 is the total number of citations those five publications receive through 2003. Our citation measure is a measure of the importance of work in a given year. It is also a measure of how basic is the research to the extent that more basic research receives in general more citations than does more applied research. The average number of citations per publication is 27.3, and 6.8% of those who publish in some year have no citations.

In figure 3 are the averages for the number of citations per publication.[9] Annual comparisons are generally statistically significant at a 5% level, but the comparison across the three samples is not as distinct as it is for

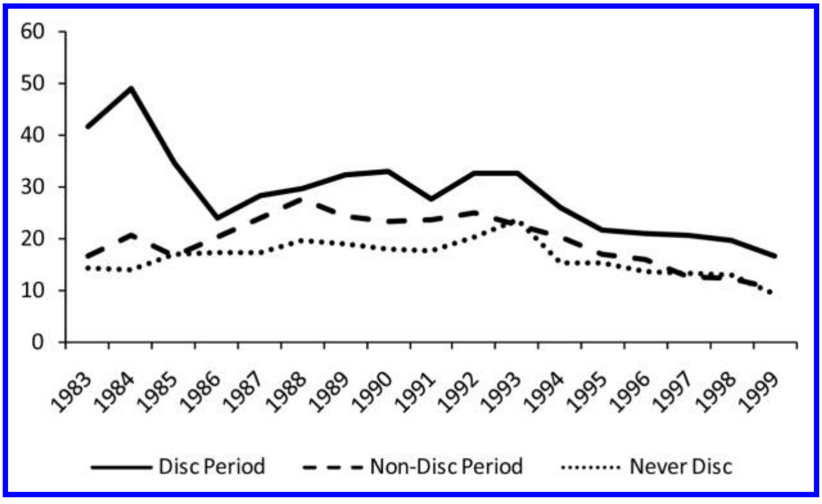

Fig. 3. Averages of citations per publication. Differences between Never Disc and Disc Period are significant at a 1% level for 14 years; two other years are significant at a 10% level. Differences between Never Disc and Non-Disc Period are significant at a 5% level for 9 years. Differences between Disc Period and Non-Disc Period are significant at a 5% level for 11 years; two other years are significant at a 10% level.

publications or funding. Since our citations are truncated in 2003, the fall-off in citations in the later years is not surprising. According to this measure, the research of faculty in the Disc Period sample has the greatest impact, and the lowest impact is research of the Never Disc sample.

As shown in figure 4, we see a similar pattern for our Narin-based measure of the number of basic publications. Recall that the measure of basic publications drops any person/year observation in years with no publications so that, unlike the prior measures, this one is conditioned both on having publications and having publications that are rated. The Disc Period sample has the highest number of basic publications. However, at a 10% level of significance, there is no significant difference between Never Disc and Non-Disc Period in 12 of the years. There is a marked increase over time in average publications for all three samples, with the largest increase being for the Disc Period sample. This is in contrast to our results on the ratio of basic to total publications shown in figure 5, in which there is a reversal in the relative positions of the Never Disc and the Disc Period samples, where the Never Disc sample has the highest fraction of basic publications. Taken together, the results in figures 4 and 5 suggest that both basic and applied effort increase with licensing, but that applied effort rises more than basic, as in Thursby et al. (2007).

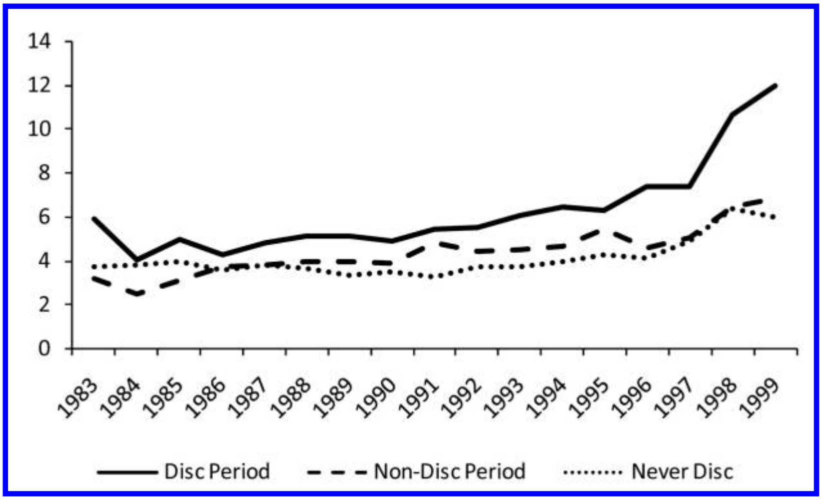

Fig. 4. Average number of basic publications. Differences between Never Disc and Disc Period are significant at a 5% level for 12 years. Differences between Never Disc and Non-Disc Period are significant at a 5% level for only 2 years; three other years are significant at a 10% level. Differences between Disc Period and Non-Disc Period are significant at a 5% level for 7 years; four other years are significant at a 10% level.

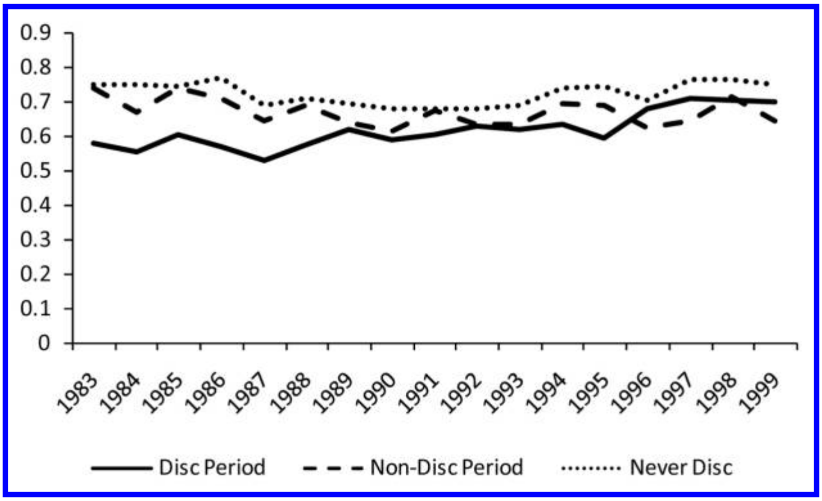

Fig. 5. Average ratios of basic publications to all publications. Differences between Never Disc and Disc Period are significant at a 5% level for 10 years; four other years are significant at a 10% level. Differences between Never Disc and Non-Disc Period are significant at a 5% level for only 3 years; three other years are significant at a 10% level. Differences between Disc Period and Non-Disc Period are significant at a 5% level for only 3 years; four other years are significant at a 10% level.

E. Are the Biological Sciences Different?

According to our general characterization of basic and applied research, research directed at understanding fundamental aspects of phenomena can also (from its inception) yield results that fit specific needs or applications. While this characterization can apply to work in many fields, it is generally thought to be particularly salient for the biological sciences. In our example of research into the protein-folding problem, research on how proteins function is fundamental, but from the outset both the researcher and funding agencies know that is it quite likely to lead directly to results with medical applications. This dual use nature of much research in biological sciences is inherent in the National Institutes of Health (NIH) funding model, in which the institutes are organized according to diseases. Thus, while the research is typically quite basic, it is by definition clearly placed in Pasteur's quadrant (Stokes 1997, particularly 137–38).

Further, since the 1970s there appears to be a narrowing of the time between basic research efforts and the development of commercial products or research tools in the biological sciences. As well, much of the literature on the relationship between research and commercialization has focused on the biological sciences. An interesting question, particularly as it relates to funding, research, and disclosure, is the extent to which the biological sciences are distinct.

In this section, we split our samples into one related to faculty in the biological sciences and the other related to the work of faculty in the physical sciences and engineering. Thirty-five percent of the faculty (1,754) are in the biological sciences. The percentage of biological science observations that are years in which a disclosure occurs is similar to that of the other fields. This also holds for the percentage of faculty who ever disclose. In terms of publications and the number of citations per publication, biological science faculty are not markedly different from others. The major differences across fields relate to funding and basic publications.

Even when split by field it is the case that both federal and industry funding are highest in a disclosure window and funding is lowest for faculty who never disclose. Federal funding for biological scientists tends to be flat from the mid-1980s until the end of the period. This holds for all three samples: Never Disc, Non-Disc Period, and Disc Period. In contrast, federal funding for the physical sciences and engineering is flat only for the faculty who never disclose. For faculty who ever disclose, there was growth in both disclosure and nondisclosure windows.

The large increase and decrease in industry funding from the mid-1980s to the mid-1990s reported earlier comes entirely from the engineering and, to a lesser extent, the physical science observations. For biological scientists, there was steady growth in industry funding for those in a disclosure window; otherwise, industry funding for biological scientists has been flat. Furthermore, for biological scientists in a disclosure window, average industry funding grew sharply from about $30,000 in 1996 to over $70,000 in 1999. For nonbiological science faculty in a disclosure window, there was also a rise in industry funding, but it was more modest, going from $60,000 to just over $80,000.

Information on basic publications by field is in figures 6–9. Looking first at the number of basic publications, recall that in the full sample there was rarely a significant difference between the average number of basic publications for the Never Disc and the Non-Disc Period samples (see fig. 4). It is clear from figures 6 and 7 that this result is driven primarily by the faculty in the physical sciences and engineering. For biological scientists the number of basic publications is highest for the Disc Period sample, followed by the Non-Disc Period sample. Those who never disclose generally have the least number of basic publications. This pattern is not representative of physical scientists and engineers. In the early years

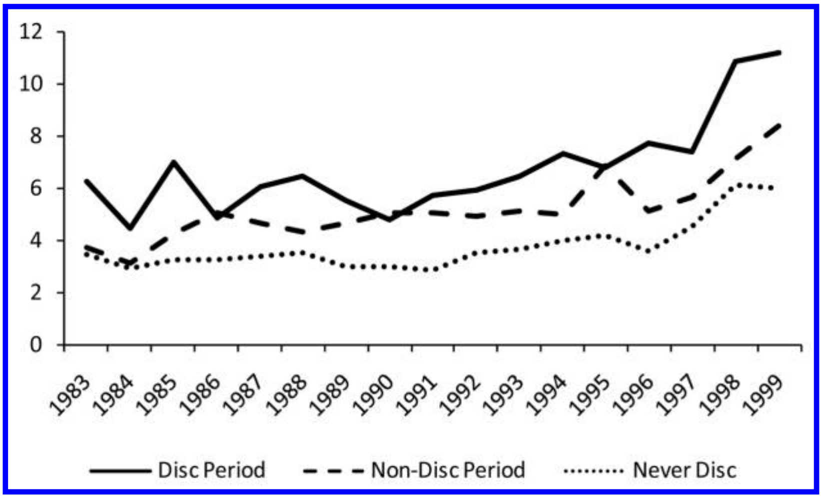

Fig. 6. Biological sciences average number of basic publications. Differences between Never Disc and Disc Period are significant at a 5% level for 14 years; one other year is significant at a 10% level. Differences between Never Disc and Non-Disc Period are significant at a 5% level for 9 years; two other years are significant at a 10% level. Differences between Disc Period and Non-Disc Period are significant at a 5% level for 6 years; two other years are significant at a 10% level.

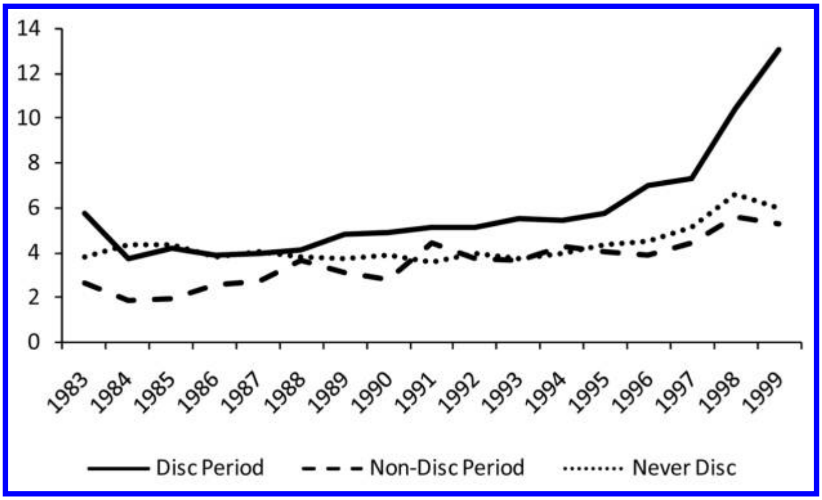

Fig. 7. Engineering and physical sciences average number of basic publications. Differences between Never Disc and Disc Period are significant at a 5% level for 6 years; two other years are significant at a 10% level. Differences between Never Disc and Non-Disc Period are significant at a 5% level for only 3 years; one other year is significant at a 10% level. Differences between Disc Period and Non-Disc Period are significant at a 5% level for 6 years; three other years are significant at a 10% level.

those who never disclose are similar to those in a disclosure window in their basic publications. The fewest basic publications are for the Non-Disc Period sample. In contrast, the latter years are ones in which the Non-Disc Period and Never Disc samples are very similar, while the Disc Period sample has significantly higher numbers of basic publications.

Figures 8 and 9 chart the fraction of publications that are basic. There is again a marked difference between faculty in the biological sciences and others. The fraction of basic publications for the biological science faculty does not vary significantly across the three samples. In contrast, for engineers and physical scientists, the highest fraction of basic publications occurs for those who never disclose. The other two samples are generally similar except in the early years.

Interestingly, about 70% of publications of biological scientists are basic, and this is similar to the basic science fraction for those who never disclose in the physical sciences and engineering.

F. Econometric Analysis

A natural question is whether the summary results presented above continue to hold when factors associated with faculty and universities

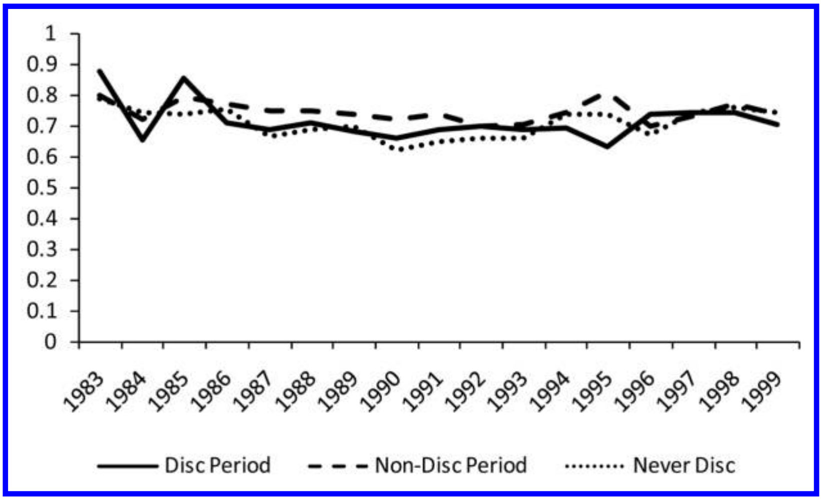

Fig. 8. Biological sciences average ratio of basic publications to all publications. Differences between Never Disc and Disc Period are significant at a 5% level for only 1 year; one other year is significant at a 10% level. Differences between Never Disc and Non-Disc Period are significant at a 5% level for only 2 years; one other year is significant at a 10% level. Differences between Disc Period and Non-Disc Period are significant at a 5% level for only 1 year.

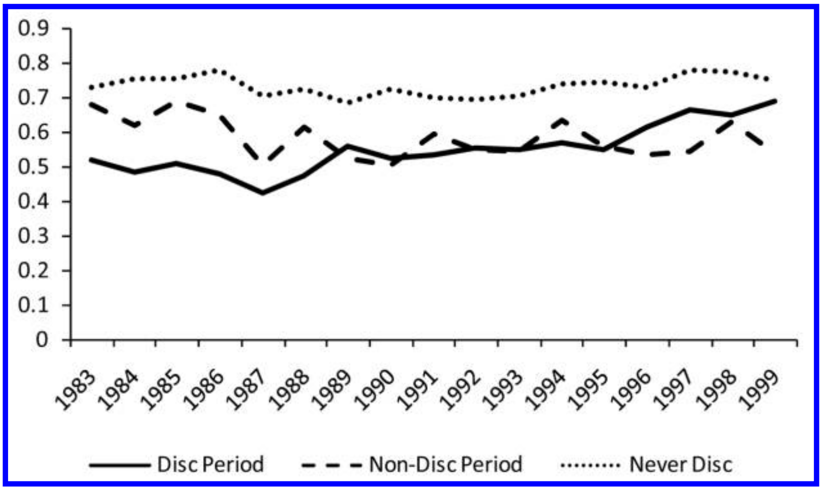

Fig. 9. Engineering and physical sciences average ratio of basic publications to all publications. Differences between Never Disc and Disc Period are significant at a 5% level for 15 years; one other year is significant at a 10% level. Differences between Never Disc and Non-Disc Period are significant at a 5% level for 15 years. Differences between Disc Period and Non-Disc Period are significant at a 5% level for only 2 years; three other years are significant at a 10% level.

are controlled for. In Thursby and Thursby (2008) we formulate a series of econometric models to explain sponsored research funding, publications, citations per publication, and the number and fraction of basic publications controlling for, among other things, the age of the faculty, their major field of research (biological sciences, engineering, or physical sciences), gender, whether they have tenure, the year of their PhD, and a measure of the academic quality of their department. The analysis also controls for university and year. In the funding equations we control for prior-year funding as well as their research output in the prior year and the current level of the other type of funding.[10] The publication, citation, and basic regressions control for prior-year funding. In all models we include the following measures of disclosure activity: disclosure activity in the year before the observation, the cumulative number of disclosures in prior years, and an indicator of whether the faculty member ever disclosed during their years in the sample.

While the disclosure variables in the econometrics do not match exactly those considered in Sections IV.C–IV.E, broadly speaking the results paint the same picture. We find that those who ever disclose publish significantly more and have significantly more federal and industry funding. Disclosure in the prior year also has a significantly positive effect on these measures of research activity, as well as citations per publication. However, the ever disclose measure of disclosure has no significant effect on citations per publication.

By including cumulative disclosures, we are able to discern whether long-term disclosure activity is more or less likely to show diversion from traditional research activity. For example, the number of cumulative disclosures has a negative effect on federal funding, so that while some disclosure activity is positively related to funding, a great deal of disclosure activity can have a net negative effect. However, in terms of the number of publications, cumulative disclosures mirror our other result, that is, they increase the number of publications. As with the ever disclose measure, cumulative disclosures have no effect on citations.

The econometric evidence on disclosure and basic publication is more mixed and depends on the measure of disclosure and faculty discipline. For the entire sample, cumulative disclosures have a significantly positive effect on the number of basic publications, and those who ever disclose have a lower fraction of basic research. If we confine attention to only engineering and physical science faculty, only cumulative disclosure has a significant effect on the number of basic publications, while for the biological sciences, only ever disclose has a significant positive effect on the number of basic publications. Nonetheless these results support the results of figures 6 and 7 and the simulation results using the production function specifications discussed in Section II.

Regarding the ratio of basic research, the results for engineering and physical science faculty are more mixed than shown in figure 9. That is, the ratio of basic research is significantly lower from those who ever disclose, but cumulative disclosure is positively related to the ratio of basic research. For the biological scientists our econometric results are similar to those in figure 8, in that for only one measure of disclosure (the number of cumulative disclosures) do we find a significant difference. In that case the ratio is lower for those with more cumulative disclosures.

Thus, broadly speaking, the econometric results support the notion that while licensing attracts researchers to applied projects, it also increases overall publication activity so that in many cases basic publication counts rise. The overall publication results are quite strong and consistent with the Thursby et al. (2007) simulation results using production specifications 1 and 3. While we report mixed results on basic publications depending on disclosure measure, one point is clear. None of the regressions lend support to the simple "either-or" specification that predicts a reduction in publication activity.

V. Conclusion

The central issue we consider is whether university patent licensing, afforded by the Bayh-Dole Act, has diverted universities away from their basic research mission. The act, passed in 1980, was intended to stimulate the transfer of federally funded research to industry. While statistics on licensing activity suggest that it has served this purpose, they have also fueled debates as to whether licensing has also led faculty to abandon basic research agendas. Our evidence, as well as that of others (Azoulay et al. 2007), suggests that while faculty have increasingly participated in such commercial activity, the implications for research are not as dire as the popular press reports (Washburn 2005; Greenberg 2007; Rae-Dupree 2008).

Taken together, our results on disclosure, funding, and publications (their nature and impact) lend credence to the notion that, rather than diverting faculty research, licensing is part of a flurry of activities that can be associated with fundamental discoveries from fairly basic research. Our earlier example from the Lindquist lab is a case in point. From the early 1980s Lindquist's work focused on protein function, and in 1993 she published a number of influential papers examining the role of heat shock proteins and thermotolerance in yeast cells (Parsell et al. 1993; Parsell and Lindquist 1993; Xu and Lindquist 1993). These three publications alone have received 1,301 citations in ISI-tracked journals to date. Her first patent application was in 1994 (involving mechanisms to reduce stress in plants). Since then she has been listed as an inventor on 21 other U.S. utility patent applications, but there is no evidence of a decline either in her publications or in their scientific significance. Since 1994, she has published 143 additional papers, which have received over 10,622 citations in ISI-tracked journals. Moreover, all but one of her publications are in journals rated as a 4 (the most basic rating) in Narin's classification. By Lindquist's own characterization of her research in our interview, even her papers dealing with specific diseases report very basic research on the biophysics of protein function.

Our most striking empirical result is the strong positive relationship between publication and disclosure activity. As shown in figure 10, Lindquist's work shows a similar pattern (albeit measured by publications and patent applications—for which there would have been disclosures). Publications and patents track each other quite closely. Interestingly, if one looks at Lindquist's annual publications after her first patent, the rate doubled from 5 to 10 per year between 1994 and 2001.

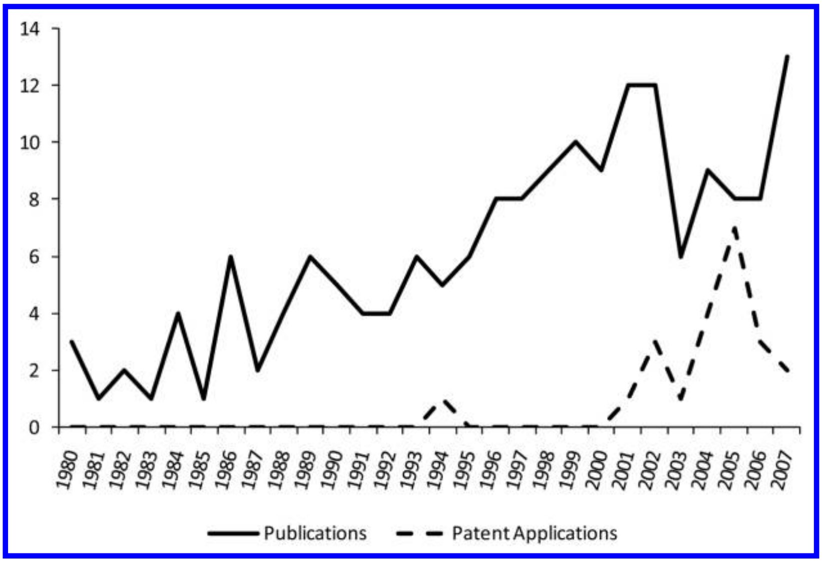

Fig. 10. Lindquist count of publications and patent applications

Our results, as well as those of other empirical studies that fail to find a diversion of scientists away from basic research, need to be interpreted with care. First, our measures of basic research may simply be too crude to distinguish basic from more applied work. Here, again, our Lindquist example is useful. All but one of her publications appear in journals listed as a 4 in Narin's 4-point rating. Yet, by our conceptual characterization, the work by Outeiro and Lindquist (2003) is about general protein function, while Willingham et al. (2003) reports implications for specific diseases. For this example, citations may more accurately depict distinctions, as the general paper has received 125 citations, while Willingham et al. (2003) and the two other papers in the same year on specific diseases received a total of 207 citations.

Second, none of the empirical work on this topic is capable of discerning whether scientists have been diverted from purely curiosity-driven basic research (Bohr's quadrant in the lexicon of Stokes [1997]) to basic research aimed at specific problems (Pasteur's quadrant). It is, of course, not clear whether such diversion is good or bad. Further, existing empirical studies have, of necessity, been primarily focused on older cohorts of faculty. Recent cohorts may have been attracted to a faculty career path in part because of increased licensing activity in universities. If this is the case, diversion of faculty is likely to show up only in future empirical studies dominated by recent cohorts.

Our conceptual framework has strong policy implications. First, once one goes beyond the simplistic notion of basic and applied research as distinct, there is no reason a priori to believe that university licensing should tarnish the basic research enterprise. Certainly we have found no empirical results suggesting that Bayh-Dole has compromised university research. Second, the complementarity of basic and applied research bolsters the National Science Council's call for increased federal funding for basic research. If, indeed, much of the basic research conducted readily improves the productivity of applied research, increased federal funding for universities will have a larger impact. The same argument also supports the council's recommendation for increased actions by industry, the academic sector, and professional organizations to encourage greater intellectual exchange between industry and academic institutions (National Science Board 2008b). Complementarity also argues against the wisdom of the NIH ethics ban on consulting.

Also recall that the positive effects of applied activity in our conceptual model rely on applied research being publishable. In addition, the simulation results we reported here are based on averages across parameters. If the financial returns to licensing are extreme, they can reduce the amount of basic research (Thursby et al. 2007). Thus, we call into question the notion that universities should count patents in tenure decisions and annual pay raises. To the extent that applied research is publishable, counting patents double-counts some aspects of productivity. Also counting patents increases the returns to licensing, with the potential negative effects noted above.

In closing, we make two suggestions for further research. First, while we have not related funding, disclosure, and publication in any causal way, it is quite likely that the patterns we observe are as much a function of funding as the legal environment for licensing. While this has been discussed in other contexts (Cohen et al. 1998), there is little research in this regard. Second, much of our understanding of faculty research choices comes from thinking about individual research choices. But science and engineering are conducted in labs. If, as we suggest, basic science has not suffered from licensing activity, it may be a result of increased lab funding. Thus, basic research that spawns both further basic and applied questions may enhance the lab's ability to attract funding, allowing the lab to take advantage of economies of scale and/or scope.

It is also important to put our discussion in a broader perspective. The question of how faculty research is affected by license opportunities is but one of many issues about the interface between university research and commerce. Just in the context of patent licensing, there are other issues such as how tying up research with licensed commercial application affects the ability of others to use the research (see, e.g., Murray and Stern 2007; Cohen and Walsh 2008; Thursby and Thursby 2008). There are also questions as to how the growth of licensing relates to aspects of public policy well beyond Bayh-Dole, such as increased patentability of bioengineering and software inventions enabled by the Supreme Court (Mowery et al. 2004). We abstract from these issues here. While we are able to relate licensing activity to faculty funding, we do not examine the extent to which industry funding for research upfront (i.e., sponsored research as opposed to ex post licensing to industry) can skew either the research itself or its dissemination (Rosenberg and Nelson 1994). There are also much broader issues related to university funding that we do not address, such as the pros and cons of a variety of commercial activities in universities, such as sports, medical services, and so forth (Noll 1998; Bok 2003).

Endnotes

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1. An invention disclosure is the formal document filed by a faculty member with her university technology transfer office when she believes she has an invention with commercial potential. Note that many of the respondents to the AUTM survey report for multiple institutions (e.g., the University of California System reports as a single unit).
2. For example, according to the Office of Management and Budget definition, basic research is directed at understanding fundamental aspects of phenomena and applied research is directed toward determination of the means by which a specific need might be met.
3. A number of European studies also find this relationship (Geuna and Nesta 2006; Meyer 2006; Van Looy, Callaert, and Debackere 2006; Breschi, Lissoni, and Montobbio 2008; Czarnitzki, Glanzel, and Hussinger 2009). Because the policy context is quite different from that in the United States, we do not discuss them here.
4. Half of the firms in an industry survey noted that they include delay of publication clauses in at least 90% of their university contracts (Thursby and Thursby 2004). The average delay is nearly 4 months, with some firms requiring as much as a year's delay.
5. Unfortunately, we do not know whether faculty disclosed in a year before or after they are in the sample.
6. We started with 1983 so as to be well past the date of passage of the Bayh-Dole Act of 1980. Universities supplied us with data as far back as disclosure information could easily be retrieved. The 1996 end was for Purdue University. Purdue was the basis for our pilot study in this project, and that pilot was initiated in 1997.
7. We also considered a disclosure window to include only the year in which a disclosure was made. Results are very similar to those presented here.
8. There are 20 observations on federal funding that are in excess of $50 million. We have dropped these outliers from the analysis of federal funding. Inclusion leads to a "noisier" set of data and also to roughly the same results except that Non-Disc Period and Never Disc are very close for the last 5 years.
9. Citations per publication are recorded as a zero if there are no publications.

10. We use instrumental variables estimation to account for possible simultaneity between sources of funding.

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