

An empirical analysis of the propensity of academics to engage in informal university technology transfer.

By: Albert N. Link, Donald S. Siegel and Barry Bozeman

[Link, A. N.](#), Siegel, D. S., & Bozeman, B. (July 11, 2007). An empirical analysis of the propensity of academics to engage in informal university technology transfer. *Industrial and Corporate Change*, 16, 4, 641-655.

This is a pre-copy-editing, author-produced PDF of an article accepted for publication in *Industrial and Corporate Change* following peer review. The definitive publisher-authenticated version is available online at:

<http://icc.oxfordjournals.org/content/16/4/641.abstract?sid=2f2dffc3-5432-4358-b048-aa8c41a5a130>.

Abstract:

Formal university technology transfer mechanisms, through licensing agreements, research joint ventures, and university-based startups, have attracted considerable attention in the academic literature. Surprisingly, there has been little systematic empirical analysis of the propensity of academics to engage in informal technology transfer. This paper presents empirical evidence on the determinants of three types of informal technology transfer by faculty members: transfer of commercial technology, joint publications with industry scientists, and industrial consulting. We find that male, tenured and research-grant active faculty members are more likely to engage in all three forms of informal technology transfer.

Keywords: technology transfer | licensing agreements | research partnerships | research joint ventures | university based startups | commercial technology

Article:

1. Introduction

The enactment of the Bayh-Dole Act in 1980 was followed by a rapid rise in formal commercial knowledge transfers from US universities to firms through such mechanisms as licensing agreements, research joint ventures, and university-based startups.¹ Universities have welcomed this trend because formal technology transfer can potentially generate large sums of revenue, as well as build relations with external stakeholders and enhance economic growth and development in the local region. A concomitant trend has been a burgeoning literature on the managerial and policy implications of such formal technology transfers.

Most researchers who assess university technology transfer have examined institutions that have emerged to facilitate commercialization, such as university technology transfer offices (TTOs),

industry–university cooperative research centers, science/research parks, and incubators. However, certain research questions are better addressed by focusing directly on agents involved in technology commercialization, such as academic scientists. A smaller literature has emerged in which individual-level behavior relating to formal technology transfer mechanisms is studied. Specifically, several authors have examined the determinants and outcomes of faculty involvement in university technology transfer, such as their propensity to patent, disclose inventions, publish with industry scientists, and establish university-based startups.²

While formal technology transfer mechanisms have attracted considerable attention in the academic literature and popular press (e.g. Bozeman, 2000; Siegel and Phan, 2005), there has been little systematic empirical analysis of informal technology transfer mechanisms. We mean by formal technology transfer mechanisms ones that embody or directly result in a legal instrumentality such as, for example, a patent, license or royalty agreement. An informal technology transfer mechanism is one facilitating the flow of technological knowledge through informal communication processes, such as technical assistance, consulting, and collaborative research. While formal technology transfer mechanisms sometimes result ultimately in formal instrumentalities, they often do not and there is not always an expectation that they will. Formal technology transfer is focused on allocation of property rights and obligations, whereas with informal technology transfer, property rights play a secondary role, if any, and obligations are normative rather than legal.

In extensive interviews of faculty members, Siegel et al. (2003, 2004) reported a key stylized fact: many faculty members are not disclosing their inventions to their university. Furthermore, these authors also found that even when an invention is publicly disclosed, some firms will contact scientists directly and arrange to work with them through informal technology transfer. Markman et al. (2006a,b) recently documented that many technologies are indeed “going out the back door.” Taken together, these findings suggest that channels of informal technology transfer may be prevalent and important for university administrators to understand given their objective to formalize such activities.

The purpose of this paper is to present empirical evidence—the first systematic empirical evidence to our knowledge—on the extent of and determinants of informal technology transfer by university faculty. Our empirical analysis is based on information collected through an extensive survey of university scientists and engineers. We identified faculty who were involved in several dimensions of informal technology transfer activity, and we then correlated the likelihood of such involvement with selected faculty and institutional characteristics.

The remainder of the paper is organized as follows. Section 2 presents a discussion of the extant literature and from that literature we identified factors that are hypothesized to be associated with faculty members engaging in informal technology transfer. Section 3 describes the data set and the econometric models used to test these hypotheses. Section 4 summarizes our empirical findings, and Section 5 offers concluding observations, prefaced by a discussion of the caveats associated with this study.

2. Technology transfer: brief overview of the literature

Before contemplating the determinants of the propensity of faculty members to engage in informal technology transfer, it is useful to consider the goals, norms, standards, and values of academic scientists. A key objective of academic scientists is recognition within the scientific community. This results primarily from scholarly papers published in leading journals; presentations at eminent institutions, conferences, and workshops; and receipt of extramural research grants. Untenured faculty members have a strong incentive to pursue such goals because they are requirements for promotion and tenure at research universities.

It is also important to note that university scientists are also motivated by personal financial gain, as well as the need to secure additional funding for physical and human capital required for additional experimental research and professional advancement. Key resources include laboratory equipment and facilities, graduate assistants, and post-doctoral fellows. The norms, standards, and values of scientists reflect an organizational culture that values creativity, innovation, and especially an individual's contribution to the advancement of knowledge through basic research.

Siegel et al. (2003) and Siegel et al. (2004) conducted over 100 structured interviews of academic scientists who had interacted with their university TTO. Their qualitative research revealed that many academics perceive, among other things, that there are insufficient rewards for faculty involvement in university technology transfer. Of particular importance for faculty involvement are the terms of the university royalty distribution formula that determines the fraction of the licensing revenue that is allocated to the faculty member who developed the new technology.

Quantitative research has confirmed the importance of the university royalty distribution formula. Using data on 113 US TTOs, Link and Siegel (2005) reported that universities allocating a higher percentage of royalty payments to faculty members are more productive in technology transfer activities. This finding was independently confirmed in Friedman and Silberman (2003) and Lach and Schankerman (2004), each using slightly different data and methodologies.

Non-pecuniary rewards, such as credit towards promotion and tenure, are also relevant factors. Some academic respondents suggested to Link and Siegel (2005) that involvement in technology transfer might be detrimental to their careers. Many faculty expressed intense frustration with the university bureaucracy. Some pointed to concerns about licensing officers: some mentioned the high rate of turnover among licensing officers, which is detrimental towards the establishment of long-term relationships with either the TTO or with firms; and still others mentioned insufficient business and marketing experience within the TTO and the possible need for incentive compensation.

Other authors have explored the role of organizational incentives in university technology transfer from a theoretical standpoint. Jensen et al. (2003) modeled the process of faculty disclosure and university licensing through a TTO as a game. The principal is the university administration, while the faculty and the TTO are agents who maximize expected utility. The authors treated the TTO as a dual agent (i.e., an agent of both the faculty and the university). Faculty members must decide whether to disclose the invention to the TTO and at what stage (i.e., whether to disclose at the most embryonic stage or wait until it is a laboratory prototype).

University administration influences the disclosure incentives of the TTO and faculty members by establishing university-wide policies for the shares of licensing income and/or sponsored research. If an invention is disclosed, the TTO decides whether to search for a firm to license the technology and then negotiates the terms of the licensing agreement with the licensee. Quality is incorporated in their model as a determinant of the probability of successful commercialization. According to the authors, the TTO engages in a balancing act in the sense that it can influence the rate of invention disclosures, evaluate the inventions once they are disclosed, and negotiate licensing agreements with firms as the agent of the administration.

Jensen et al. (2003) theoretical analysis generates some interesting empirical predictions. For instance, in equilibrium, the probability that a university scientist discloses an invention and the

stage at which this happens is related to the pecuniary reward from licensing, as well as faculty quality. The authors tested the empirical implications of the dual agency model based on an extensive survey of the objectives, characteristics, and outcomes of licensing activity at 62 US universities.³ Their survey results provide empirical support for the hypothesis that the TTO is a dual agent. They also found that faculty quality is positively associated with the rate of invention disclosure at the earliest stage and negatively associated with the share of licensing income allocated to inventors.

Social networks appear to play an important role in university-industry technology transfer processes. These networks include academic and industry scientists, and perhaps, university administrators, TTO directors, and managers/entrepreneurs (Powell, 1990; Liebeskind et al., 1996). Social networks that allow knowledge transfer appear to work in both directions. Scientists who were interviewed noted that interacting with industry enabled them to conduct better basic research, a finding that has also been documented in biotechnology industries (Zucker and Darby, 1996).

Murray (2004) studied social networks from the perspective of the academic careers of biotechnology scientists and examined, for a small sample of scientists, the relationship between academic careers and their social capital. Murray showed that social capital affected the success of scientist's relationship with firms, as did their human capital. Human capital is often associated with tacit knowledge, and tacit knowledge engenders scientists to firms.⁴

Institutional factors and cultural norms across scientific fields may also influence technology transfer activity. Owen-Smith and Powell (2001, 2003) compared faculty involvement in technology transfer in the life sciences and physical sciences. They reported substantial variation in perceptions across scientific fields on the outcomes of patenting. On the one hand, life scientists appear to be more concerned about the proprietary benefits of patents and using them to obtain leverage with firms. On the other hand, physical scientists patent so that they can have the freedom to publicize their work without fear of losing potentially valuable intellectual property rights, and also to gain leverage with the university. The authors concluded that institutional success in technology transfer depends on faculty attitudes toward the TTO; perceptions about the ease of working with the TTO appear to be an important factor in faculty decisions to patent. They also argued that a crucial first step in the process of technology transfer is for faculty members to disclose inventions, which will require effort on the part of the TTO to elicit disclosures.

Some authors have recently explored the outcomes of research collaborations among industry scientists and university scientists. Adams et al. (2005) assessed scientific teams and institutional collaborations, at the level of the individual researcher. The authors analyzed data from 2.4 million scientific papers published by researchers at 110 top US research universities during the 1981–1999 period. These scientific papers accounted for a substantial share of published basic research conducted in the United States during this period. The authors measured team size by the number of authors on a scientific paper. Using this measure they found that both team size and the rate of collaboration have increased substantially over the 19-year period.

Placement of former graduate students was found to be a key determinant of institutional collaborations, especially collaborations with firms and with foreign scientific institutions. Finally, the evidence suggested that scientific output and influence increase with team size and that influence rises along with institutional collaborations. Because increasing team size implies an increase in the division of labor, these results are in a way suggestive that scientific productivity increases with the scientific division of labor.

Hertzfeld et al. (2006) interviewed then surveyed chief intellectual property attorneys at 54 R&D-intensive US firms concerning intellectual property protection mechanisms related to university patents. They found that firms expressed great difficulty in dealing with university TTOs on intellectual property issues, citing the inexperience of the TTO staff, their lack of general business knowledge, and their tendency to inflate the commercial potential of the patent. The authors reported that firms were similarly frustrated and were inclined, when possible, to bypass the TTO and deal directly with the university scientist or engineer.

Dietz and Bozeman (2005) analyzed the career paths of scientists and engineers working at US university research centers. The authors followed career transitions within the industrial, academic, and governmental sectors and their relation to the publication and patent productivity of these researchers. They hypothesized that among university scientists, inter-sectoral changes in jobs throughout their careers provided access to new social networks and scientific and technical human capital, which resulted in higher productivity. To test this hypothesis, the authors collected and coded the academic vita of each of the 1,200 research scientists and engineers. In addition, patent data were collected from the US Patent and Trademark Office and linked to career data on these researchers.

Dietz and Bozeman (2005) concluded that the career paths of academic scientists and engineers affiliated with university research centers are quite different than those characterized in the standard literature on career transitions of researchers. The wave of center creation activity that began in the early 1980s has resulted in markedly different academic careers and greater ties between universities and industry. At least within the domain of university research centers, there seems to be considerable industrial ties, reflected in changes in careers and other factors, which are associated with different productivity outcomes.

In sum, the extant literature on institutional productivity in licensing, patenting, and entrepreneurial startups and the role of individual scientists in that process suggests that faculty members may have strong incentives to engage in informal technology transfer. In the following sections of this paper, we present systematic empirical evidence on the propensity of faculty members to circumvent the TTO through information technology transfer.

3. Data set and econometric model

Our data on informal technology transfer are derived from the Research Value Mapping Program Survey of Academic Researchers.⁵ Survey data were collected from a sample of university scientists and engineers with a Ph.D. at the 150 Carnegie Extensive Doctoral/Research Universities during the time period spring 2004 to spring 2005.⁶ The sample of researchers selected to receive the survey was not random but rather proportional to the numbers of academic researchers in the various fields of science and engineering, and it was balanced between randomly selected men and women.⁷

The measures of informal technology transfer considered herein are based on faculty responses to the following three statements in the survey:

During the past 12 months:

1. I worked directly with industry personnel in an effort to transfer or commercialize technology or applied research.
2. I co-authored a paper with industry personnel that has been published in a journal or refereed proceedings.

3. I served as a formal paid consultant to an industrial firm.

To the best of our knowledge, this study represents the first systematic collection of such information from a large cross-section of university scientists and engineers. The three dependent variables in our econometric analysis relate to these alternative mechanisms of informal faculty technology transfer.⁸

From the sampling population of 1514 full-time tenured or tenure-track scientists and engineers, nearly 52% responded that they had some working relationship with industry during the past 12 months; of these faculty, 16% have been involved in the transfer of commercial technology, 15% have co-authored with industry personnel, and 18% have served as formal consultants with industry.

The empirical model used to quantify the relationship among these measure of informal technology transfer and faculty and institutional characteristics is:

$ITT = COMMERC, JOINTPUB, \text{ or } CONSULT = f(\mathbf{X})$.(1) where *ITT* represents three dimensions of informal technology transfer: involvement in activity to transfer or commercialize technology (*COMMERC*), involvement in joint publications (*JOINTPUB*), and consulting (*CONSULT*). Independently, Cohen *et al.* (2002) identified such dimensions of information technology transfer. And, with reference to equation (1), \mathbf{X} is a vector of faculty characteristics, including gender (*GENDER*, males = 1; 0 otherwise); faculty tenure (*TENURE*, tenured = 1; 0 otherwise; or years with tenure, *YRSTEN*); preeminence of the faculty member as measured by the percent of time spent on grants-related research (*GRANTRES*); and the scientific or engineering discipline of the faculty member.

This descriptive model is based in part on predictions from the extant literature and in part on the availability of data. Gender is a control variable. The academic status and past research success of each faculty member is proxied by the tenure variables. Although this faculty dimension has not previously been investigated empirically, its inclusion in our model is motivated from the theory of social networks, with emphasis on both the demand side and supply side. While many faculty may be willing to supply their research capabilities to firms, those faculty most credentialed will logically be in greater demand, as Murray's (2004) findings suggest. Also, the confirmation of tenure signals to firms what we refer to as "accumulative advantage." Tenured faculty have had a longer time to develop industry networks as well as skills and a body of accepted research potentially useful to industry. And, tenured faculty may have a stronger inclination to in fact supply their talents to industry. The fact that the tenure hurdle has been vaulted means that such faculty may be more likely to feel the freedom to engage in activities that, while important to them and to their institution, are self-enriching.

Holding tenure constant, faculty who are more grants-research active, as proxied by the percent of time they currently allocated to grants-related research, is yet another measure of the human capital of the scientist. He or she has cleared the hurdle of peer review to receive an extramural research grant and may thus be in greater demand by industry because of their external or third-party confirmation of research excellence. It is an empirical issue whether such faculty will in fact supply their talents in the face of industry demand, all else remaining constant.

Finally, the academic discipline of each faculty member is held constant to control for, among other things, differences in what Klevorick et al. (1995) called technological opportunity.

4. Empirical results

Descriptive statistics on all of these variables are presented in Table 1. While the stratified sample is evenly split between men and women, there appears to be a high, but representative, proportion of tenured faculty members—nearly 72% of the respondents are tenured, with an average of being tenured for 16 years. The average faculty member in our sample is currently spending a little more than 24% of his or her work time on research grants.

Table 1

Descriptive statistics ($n = 1502$)

Variable	Mean	Standard deviation
<i>COMMERC</i>	0.158	0.365
<i>JOINTPUB</i>	0.146	0.353
<i>CONSULT</i>	0.180	0.385
<i>GENDER</i>	0.481	0.500
<i>TENURE</i>	0.716	0.451
<i>YRSTEN*</i>	15.87	10.89
<i>GRANTRES</i>	0.246	0.164
<i>AGE**</i>	46.31	10.37
Biology	0.079	0.270

Variable	Mean	Standard deviation
Computer Science	0.087	0.281
Mathematics	0.066	0.248
Physics	0.093	0.290
Earth and Atmospheric Science	0.105	0.307
Chemistry	0.085	0.278
Agriculture	0.080	0.271
Chemical Engineering	0.075	0.264
Civil Engineering	0.104	0.305
Electrical Engineering	0.076	0.265
Mechanical Engineering	0.091	0.288
Materials Engineering	0.060	0.237

Note : A number of faculty members were deleted from the population of 1514 because data were not reported on years with tenure or on age.

* $n = 1462$.

** $n = 1485$.

Table 2 presents econometric results from alternative specifications of equation (1). Specifications related to the results in columns (1), (5), and (9) include the dichotomous tenure variable, TENURE, while those in columns (2), (6), and (10) quantify tenure in terms of years with tenure, YRSTEN. Paralleling these specifications are others that also control for the age of the faculty member, AGE. AGE is included as an independent variable in an effort to segment the impact of tenure, per se, as a signal about faculty quality, and time, per se, as a necessary condition for being able to develop industrial relationships. As noted below, however, the AGE is generally not statistically significant.

Table 2 Probit estimates from equation (1) (standard errors in parentheses)

Independent variable	Dependent variable											
	<i>COMMERC</i>				<i>JOINTPUB</i>				<i>CONSULT</i>			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
<i>GENDER</i>	0.262* (0.08)	0.226** (0.09)	0.274* (0.09)	0.246* (0.09)	0.141*** (0.08)	0.102 (0.09)	0.098 (0.09)	0.084 (0.09)	0.391* (0.08)	0.320* (0.09)	0.379* (0.86)	0.335* (0.09)
<i>TENURE</i>	0.266* (0.10)	—	0.291* (0.11)	—	0.264* (0.10)	—	0.221** (0.11)	—	0.387* (0.10)	—	0.375* (0.11)	—
<i>YRSTEN</i>	—	0.087** (0.03)	—	0.225* (0.07)	—	0.081** (0.03)	—	0.089 (0.07)	—	0.108* (0.03)	—	0.188* (0.07)
<i>GRANTRES</i>	0.848* (0.23)	0.854* (0.23)	0.846* (0.23)	0.836* (0.23)	0.798* (0.22)	0.828* (0.23)	0.804* (0.23)	0.813* (0.23)	0.438** (0.20)	0.509** (0.21)	0.520** (0.21)	0.575* (0.21)
<i>AGE</i>	—	—	-0.0009 (0.005)	-0.201** (0.01)	—	—	-0.004 (0.005)	-0.001 (0.009)	—	—	-0.002 (0.005)	-0.012 (0.01)
Intercept	-2.363* (0.17)	-2.521* (0.21)	-2.356* (0.26)	-2.098* (0.29)	-2.219* (0.16)	-2.345* (0.26)	-2.379* (0.26)	-2.293* (0.28)	-2.091* (0.15)	-2.241* (0.19)	-2.227* (0.25)	-2.033* (0.27)
Log Likelihood	-575.9	-555.1	-569.5	-549.7	-571.9	-553.2	-565.5	-547.4	-641.8	-623.1	-633.1	-613.7
Pseudo R ²	0.110	0.101	0.114	0.115	0.164	0.164	0.164	0.162	0.185	0.185	0.185	0.184
<i>n</i>	1502	1462	1485	1462	1502	1462	1485	1462	1502	1462	1485	1462

Notes: Discipline effects are held constant; these results along with other descriptive statistics by discipline, are available from the authors. Probit results are weighted by discipline sampling proportions.

*Significant at 0.01 level; **significant at 0.05 level; ***significant at 0.10 level

The Probit estimates reported in Table 2 suggest that male faculty members are more likely than female faculty members to engage in informal commercial knowledge transfer and consulting. Recent research (e.g., Corley and Gaughan, 2005) from this same data set suggests that these gender findings may be attenuated by institutional setting. Women who are affiliated with interdisciplinary university research centers have commercial activity profiles that more closely resemble male center affiliates than females affiliated only with traditional academic departments. It is also likely the case that gender findings are explained in part by disciplinary selection effects, which we do control for in the model. Women represent a smaller portion of those disciplines and fields most active in technology transfer.

Not surprisingly, tenured faculty members are more likely than untenured faculty members to engage in all three forms of informal technology transfer. Years with tenure also has a positive impact especially on the transfer of commercial technology and on publications.

Finally, we find that faculty members who currently allocate a relatively higher percentage of their time to grants-related research are more likely to engage in all forms of informal technology transfer. Companion research using the same data as herein suggests that this is especially the case for grants and contracts from industry (Bozeman and Gaughan, 2006).

[Previous Section](#)

[Next Section](#)

5. Concluding observations

Our empirical findings should be interpreted with caution for three reasons. The first concern is possible response bias to the survey, although we weighted responses to mirror the population of scientists and engineers. Another concern is that we have simple, dichotomous measures of informal technology transfer. The latter may be problematic because such measures do not account for the extent of such activity or for the nature and characteristics of the technology that is transferred. In addition, our data do not allow us to control for the possibility that informal technology transfer, as we have measured it, in the current time period can develop into formal technology transfer in subsequent time periods. As well, our data do not allow us to explore the possibility of a complementary relationship among the three measures of information technology transfer—contemporaneously complementary or complementary over time.

And, there could be a two-stage process, or perhaps a simultaneous process, underlying our statistical analysis. The first stage might consist of the decision by the faculty member to establish a relationship with a private company; the second stage, or perhaps the simultaneous stage, might consist of the decision by the faculty member to actually engage in informal technology transfer activities. We also note that our econometric analysis does not control for the quality of the TTO, namely the competence of those in the office or the efficiency with which the office operates.

These caveats and data shortcomings aside, the results in Table 2 are the first such results and should be especially useful to university administrators. A clear finding is that tenured faculty members and those who are actively involved in research grants are more likely to engage in informal technology transfer than non-tenured faculty members. One interpretation of this result is that industry is simply more interested in interacting with more successful research faculty, a finding that is consistent with the “star scientist” phenomenon in the biotechnology industry by Zucker and Darby (1996, 2001). It is also possible that the incidence of such informal technology transfer might be a signal that technologies are going “out of the back door” and hence the university is not realizing sufficient revenue from its intellectual property portfolio. Another interpretation is that university incentives need to be properly aimed towards keeping tenured faculty members involved in formal technology transfer activities.

The results relating to research grants might imply that there is tension between grants-active faculty and university incentives to participate in university formal technology transfer activities. Generally, extramural research grants, or at least successful ones, propose research toward the basic end of the research spectrum whereas formal university technology transfer activities, or at least successful ones, are often applied in nature.⁹ Such an applied focus for research may not resonate well with many faculty members.

Hall et al. (2003: 491) conclude from their analysis of university-with-industry joint research activities that university faculty “... are included (invited by industry) in those research projects [where they] could provide research insight that is anticipatory of future research problems and [where they could] be an ombudsman anticipating and communicating to all parties the complexity of the research undertaken. Thus, one finds [university faculty] purposively involved in projects that are characterized as problematic with regard to the use of basic knowledge.” As a result, informal technology transfer is more likely to occur.

Universities establish formal technology transfer mechanisms and institutions (e.g., research/science parks and incubators) to ensure that commercialization efforts are managed through the university and that financial returns are internalized. In general, the university might want to encourage its more accomplished faculty members to participate in such internal infrastructures.

If our interpretation is correct, universities might rethink aspects of their technology transfer policies and procedures. Many universities are focusing their faculty hiring efforts on academics who have secured large research grants, which can raise its ranking and generates immediate overhead for the institution. Our results imply that this hiring strategy could lead to unintended or unanticipated results, given that such faculty members may ultimately become more involved in aspects of informal technology transfer activity outside of the university's formal infrastructure.

Instead, it seems desirable for universities to focus their efforts on changing incentive structures, so that faculty members are more likely to participate in technology transfer through their institutional roles as university faculty members rather than only as consultants (though in some instances the two roles can be complementary). From the standpoint of faculty incentives, universities could consider shifting the royalty distribution formula in favor of faculty members. This will elicit more invention disclosures and participation in formal university technology transfer. It also seems prudent for universities that place a high priority on formal technology transfer to place a higher value on patenting, licensing, and start-up formation in promotion and tenure decisions.

Acknowledgements

The research reported here was supported under grants to Georgia Tech from the Department of Energy and the National Science Foundation. This paper has benefited from the comments and suggestions of Mike Wright, Andy Lockett, and two anonymous referees.

Footnotes

* This work was performed as part of the project “Assessing Economic and Social Impacts of Basic Research Sponsored by the Office of Basic Energy Sciences,” under contract DE-FG02-96ER45562 and “Assessing R&D Projects’ Impacts on Scientific and Technical Human Capital Development” (SBR 98-18229)—Barry Bozeman, P.I.

1 For a history of the Bayh-Dole Act, see, for example, Stevens (2004); for an overview of public policy implications related to Bayh-Dole, see Mowery et al. (2004) and Link (2006).

2 See, for example, Louis et al. (1989) and Audretsch (2000).

3 See Thursby et al. (2001) for an extensive description of this survey.

4 Nicolaou and Birley (2003) hypothesized that networks with industry, “exoinstitutional research networks,” lead to scientist involvement in direct or orthodox spin out formations that do not involve the university. Relatedly, Druilhe and Garnsey (2004) examined longitudinal data from Cambridge University and found that informal relationships with industry were often precursors to a formal spin out that likewise did not involve the university.

5 This database was assembled under the sponsorship of these agencies within the Research Value Mapping Program at Georgia Tech for the purpose of understanding the teaching, research, and grant experiences of university scientists and engineers and their career trajectories.

6 See, <http://www.carnegiefoundation.org/Classification/index.htm>.

7 The target sample was 200 men and 200 women from each of the 12 National Science Foundation science and technology disciplines: biology, computer science, mathematics, physics, earth and atmospheric science, chemistry, agriculture, chemical engineering, civil engineering, electrical engineering, mechanical engineering, and materials engineering (<http://www.nsf.gov/sbe/srs/nsf03310/start.htm>). Sampling proportions by gender and field are taken into account in the weighted regressions discussed below; these weights are available from the authors upon request.

8 Data were collected on the propensity of faculty to patent with industry; but we could not determine conclusively if such patenting activity involved the TTO or not. Thus, patenting activity was not considered in the analysis below.

9 This said, it is of course the case that in some disciplines, such as biology, the distinction between basic research and applied research is blurred.

References

- Adams J, Black G, Clemmons R, Stephan P. Scientific teams and institutional collaborations: evidence from U.S. universities, 1981–1999. *Research Policy* 2005;34(3):259-286.
- Audretsch DB. Is University Entrepreneurship Different? Mimeo: Indiana University; 2000.
- Bozeman B. Technology transfer and public policy: a review of research and theory. *Research Policy* 2000;29:627-655.
- Bozeman B, Gaughan G. 'Impacts of Grants and Contracts on Academic Researchers' Interactions with Industry,' Georgia Tech Working Paper, Research Value Mapping Program; Atlanta, GA. 2006.
- Cohen WM, Nelson RR, Walsh JP. Links and impacts: the influence of public research on industrial R&D. *Management Science* 2002;48:1-23.
- Corley E, Gaughan M. Scientists' participation in university research centers: what are the gender differences?'. *Journal of Technology Transfer* 2005;30:371-381.
- Dietz JS, Bozeman B. Academic careers, patents, and productivity: industry experience as scientific and technical human capital. *Research Policy* 2005;34(3):349-368.
- Druilhe C, Garnsey E. Do academic spin-outs differ and does it matter? *Journal of Technology Transfer* 2004;29:269-285.
- Friedman J, Silberman J. University technology transfer: do incentives, management, and location matter? *Journal of Technology Transfer* 2003;28:81-85.
- Hall BH, Link AN, Scott JT. Universities as research partners. *Review of Economics and Statistics* 2003;85:485-491.
- Hertzfeld HR, Link AN, Vonortas NS. Intellectual property protection mechanisms in research joint ventures. *Research Policy* 2006;35:825-838.
- Jensen R, Thursby JG, Thursby MC. The disclosure and licensing of university inventions: the best we can do with the S**t we get to work with. *International Journal of Industrial Organization* 2003;21:1271-1300.
- Klevorkck AK, Levin RC, Nelson RR, Winter SG. On the sources and significance of interindustry differences in technological opportunities. *Research Policy* 1995;24:185-205.
- Lach S, Schankerman M. Royalty sharing and technology licensing in universities. *Journal of the European Economic Association* 2004;2:252-264.

Liebeskind J, Oliver A, Zucker LG, Brewer M. Social networks, learning, and flexibility: sourcing scientific knowledge in new biotechnology firms. *Organization Science* 1996;7:428-443.

Link AN. *Public/Private Partnerships: Innovation Strategies and Public Policy Alternatives*. New York: Springer; 2006.

Link AN, Siegel DS. Generating science-based growth: an econometric analysis of the impact of organizational incentives on university–industry technology transfer. *European Journal of Finance* 2005;11:169-182.

Louis KS, Blumenthal D, Gluck ME, Stoto MA. Entrepreneurs in academe: an exploration of behaviors among life scientists. *Administrative Science Quarterly* 1989;34:110-131.

Markman GD, Gianiodis PT, Phan P. Sidestepping the Ivory Tower: Rent Appropriations through Bypassing of U.S. Universities. Mimeo; 2006a.

Markman GD, Gianiodis PT, Phan P. ‘An agency theoretic study of the relationship between knowledge agents and university technology transfer offices,’ Rensselaer Polytechnic Working Paper; Troy, NY. 2006b.

Mowery DC, Nelson RR, Sampat BN, Ziedonis AA. Palo Alto, CA: Stanford University Press; 2004. *Ivory Tower and Industrial Innovation: University-Industry Technology Transfer Before and After the Bayh-Dole Act*.

Murray F. The role of academic inventors in entrepreneurial firms: sharing the laboratory life. *Research Policy* 2004;33:643-659.

Nicolaou N, Birley S. Academic networks in a trichotomous categorisation of university spinouts. *Journal of Business Venturing* 2003;18:333-359.

Owen-Smith J, Powell WW. To patent or not: faculty decisions and institutional success at technology transfer. *Journal of Technology Transfer* 2001;26:99-114.

Owen-Smith J, Powell WW. The expanding role of university patenting in the life sciences: assessing the importance of experience and connectivity. *Research Policy* 2003;32:1695-1711.

Powell WW. Neither market nor hierarchy: network forms of organization. *Research in Organizational Behavior* 1990;12:295-336.

Siegel DS, Phan P. Analyzing the effectiveness of university technology transfer: implications for entrepreneurship education. In: Liebcap G, editor. *Advances in the Study of Entrepreneurship, Innovation, and Economic Growth*. Amsterdam: Elsevier Science/JAI Press; 2005. p. 1-38.

Siegel DS, Waldman D, Link AN. Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study. *Research Policy* 2003;32:27-48.

Siegel DS, Waldman D, Atwater L, Link AN. Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies. *Journal of Engineering and Technology Management* 2004;21:115-142.

Stevens AJ. The enactment of Bayh-Dole. *Journal of Technology Transfer* 2004;29:93-99.

Thursby JG, Jensen R, Thursby MC. Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities. *Journal of Technology Transfer* 2001;26:59-72.

Zucker LG, Darby MR. Star scientists and institutional transformation: patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences* 1996;93:709-716.

Zucker LG, Darby MR. Capturing technological opportunity via Japan's star scientists: evidence from Japanese firms' biotech patents and products. *Journal of Technology Transfer* 2001;26:37-58.