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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: knowledge transfer, joint publications with industry scientists, and consulting. We find that male and tenured faculty members are more likely to engage in all three forms of informal technology transfer. We also find that academics who allocate a relatively higher percentage of their time to grants-related research are more likely to engage in informal commercial knowledge transfer.

JEL classification: M13 ; D24; L31; O31; O32

Keywords: University Technology Transfer, Patents, Publications

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I. Introduction

The enactment of the Bayh-Dole Act in 1980 was followed by a rapid rise in formal commercial knowledge transfers from U.S. 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 (e.g. Siegel and Phan, 2005).

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 which has studied individual-level behavior relating to formal technology transfer mechanisms. Specifically, several authors have examined the determinants and outcomes of faculty involvement in university technology transfer, such as their propensity to patent, disclose inventions, co-author with industry scientists, and form

[1] For a history of the Bayh-Dole Act, see, for example, Stephens (2004); for an overview of public policy related to university patenting activity, see, for example, Mowery et al. (2004) and Link (2006).

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, patent, license or royalty agreement. An "informal" technology transfer mechanism is one facilitating the flow of technology knowledge but 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 no expectation that they will. Formal technology transfer is focused on allocation of property rights and obligations, whereas in 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, Waldman, Atwater, and Link (2003, 2004) reported a key stylized fact: many faculty members are not disclosing their inventions to their university. Furthermore, they 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, Gianiodis, and Phan (2006a, 2006b) recently documented that many technologies are indeed "going out the back door." Taken together, these findings suggest that informal channels of informal technology transfer may be prevalent and important for university administrators to understand given their objective to formalize such activities.

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

The purpose of this paper is to present empirical evidence on the 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 characteristics.

The remainder of the paper is organized as follows. Section II contains a discussion of the factors that might lead faculty members to engage in informal technology transfer, which leads to a set of testable empirical hypotheses. Section III describes the data and the econometric model we use to test these hypotheses. Section IV contains our empirical findings. The final section discusses caveats and preliminary conclusions.

II. Informal Technology Transfer

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 in leading journals; presentations at premier institutions, conferences, and workshops; and federal 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. 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 advances in knowledge (i.e., basic research).

Siegel, Waldman, Atwater, and Link (2003, 2004)) conducted over 100 structured interviews of academic scientists who had interacted with technology transfer offices. This qualitative research revealed that many academics perceive, among other things, that there are insufficient rewards for involvement in university technology transfer. Of particular importance is the "royalty distribution formula" that determines the fraction of the licensing revenue that is allocated to a faculty member who develops the new technology.

Quantitative research confirms the importance of this formula. Using data on 113 U.S. TTOs, Link and Siegel (2005) report 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 methods and data.

Non-pecuniary rewards, such as credit towards promotion and tenure, are also relevant factors. Some academic respondents even suggested that involvement in technology transfer might be detrimental to their careers. Many others expressed intense frustration with the university bureaucracy. Others 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; others mentioned insufficient business and marketing experience in 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, Thursby, and Thursby (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 treat 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 lab-scale 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, must evaluate the inventions once they are disclosed, and negotiate licensing agreements with firms as the agent of the administration.

Jensen, Thursby, and Thursby's (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 he or she discloses the invention is related to the pecuniary reward from licensing, as well as faculty quality. The authors test the empirical implications of the dual agency model based on an extensive survey of the objectives, characteristics, and outcomes of licensing activity at 62 U.S. universities.[3] Their survey results provide empirical support for the hypothesis that the TTO is a dual agent. They also find 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 is important in university-industry technology transfer processes. These networks include academic and industry scientists, and perhaps, university administrators, TTO directors, and managers/entrepreneurs (Liebeskind, Oliver, Zucker and Brewer, 1996; Powell, 1990). Social networks that allow knowledge transfer appear to work in both directions. Scientists who were interviewed noted that interacting with industry enables them to conduct "better" basic research, a finding that has been documented in biotechnology industries (Zucker & Darby, 1996).

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[3] See Thursby, Jensen, and Thursby (2001) for an extensive description of this survey.

Institutional factors and cultural norms across scientific fields also may be critical. Owen-Smith and Powell (2001, 2003) have published several papers comparing faculty involvement in technology transfer in the life sciences and physical sciences. They report substantial variation in perceptions across scientific fields on the outcomes of patenting. 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 also conclude that, on the other hand, 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 argue 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 between industry scientists and university scientists. Adams, Black, Clemmons, and Stephan (2005) assess scientific teams and institutional collaborations, at the level of the individual researcher. The authors analyze data from 2.4 million scientific papers published by researchers at 110 top U.S. research universities during 1981-1999. These papers account for a substantial share of published basic research conducted in the U.S. during this period. The authors measure team size by the number of authors on a scientific paper. Using this measure they find that both team size and the rate of collaboration have increased substantially over the 19-year period.

Placement of former graduate students is found to be a key determinant of institutional collaborations, especially collaborations with firms and with foreign scientific institutions. Finally, the evidence suggests 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, Link, and Vonortas (2007) surveyed and interviewed chief intellectual property attorneys at 54 R&D-intensive U.S. 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 technology transfer staff, their lack of business knowledge, and their tendency to inflate the commercial potential of the patent. The authors report that firms were included, if possible, to by-pass the TTO and deal directly with the university scientist or engineer.

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

Dietz and Bozeman (2005) conclude 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 remainder of this paper, we present the first systematic empirical evidence on the propensity of faculty members to circumvent the TTO.

III. Data and Econometric Model

Our data on informal technology transfer are derived from the Research Value Mapping Program (Georgia Tech) Survey of Academic Researchers.[4] 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.[5] 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 balanced between randomly selected men and women.[6]

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

During the past 12 months:

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

[4] 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.
[5] See, http://www.carnegiefoundation.org/Classification/index.htm.
[6] 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..

dependent variables in our econometric analysis relate to these alternative mechanisms of informal faculty technology transfer.

From the sampling population of 1,514 full-time tenured or tenure-track scientists and engineers, nearly 52 percent responded that they had some working relationship with industry during the past 12 months; and of those faculty (n=782), 16 were deleted from our analysis because of other relevant missing information. Of the remaining 766 faculty members, 31 percent have been involved in transferring technology for commercialization purposes, 28 percent have co-authored with industry personnel, 35 percent have served as formal consultants, and 10 percent have been involved in patenting activity.

Our empirical model is:

(1) *ITT* = *COMMERC*, *JOINTPUB*, or *CONSULT* = f (**X**).

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, Nelson, and Walsh (2002) identified such dimensions of *ITT*. And, with reference to equation (1), **X** is a vector of faculty characteristics, including *GENDER* (males = 1; 0 otherwise), *TENURE* (tenured = 1; 0 otherwise), preeminence of the faculty member, as measured by the percent of time spent on grants-related research (*GRANTRES*); and dichotomously the scientific or engineering discipline of the faculty member.

IV. 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 74 percent of the respondents are tenured. The average faculty member in our sample is spending a little more than twenty five percent of his/her work time on research grants.

Table 2 presents econometric estimates of equation (1). The Probit estimates reveal 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. This is due in part to what we call "accumulative advantage." Tenured faculty members have had a longer time to develop skills and produce bodies of work useful for industry. Related, they have had a longer period to develop network ties that may include industrial personnel. It is also important to remember that tenure has a censoring effect. That is, tenure can be presumed to be a rough proxy for quality and, related, some percentage of the tenure-track faculty members will not pass this standard. For all these reasons, tenured faculty could be expected to be in greater demand by industry. They may also have a stronger inclination to supply such activity. The fact that the tenure hurdle has been vaulted means that these faculty are more likely to feel the freedom to engage in activities that, while important to them and to their institution, may have limited benefit for tenure.

Finally, we find that faculty members who allocate a relatively higher percentage of their time to grants-related research are more likely to engage in informal commercial knowledge transfer and to publish with industry scientists. 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).

Table 3 contains the econometric estimates of equation (1), based on an alternative measure of faculty tenure, namely years with tenure, *YRSTENURE*. These Probit estimates enhance the results presented in the previous table. Specifically, we find that the longer a faculty member has been tenured, the higher the probability that he/she will be involved in all forms of informal technology transfer. These results reinforce the accumulative advantage and demand interpretations provided above.

V. Caveats and Preliminary Conclusions

Our empirical findings should be interpreted with caution for three reasons. The first concern is possible response bias. 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. A third concern is that there is either a two-stage process, or perhaps a simultaneous process, underlying our statistical analysis. The first stage consists of the decision by the faculty member to establish a relationship with a private company. The second stage, or perhaps the simultaneous stage, consists of the decision by the faculty member to actually engage in informal technology transfer activities. It is important to note that the results presented in Tables 2 and 3 are derived only from the second stage, although our empirical analysis implies that this is the more relevant stage.[7] 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.

Despite these caveats, the results in Tables 2 and 3 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

[7] We attempted to capture the underlying two-stage process by analyzing the entire sample of 1,514 faculty members. We coded those faculty with no relationship with private sector companies as 0, those with a relationship but not one that involved an informal technology transfer as 1, and those with a relationship that does involved informal technology transfer as 2. A multinomial Logit estimation of this model, as a function of **X**, added no additional information to the findings in Tables 2 and 3.

industry is simply more interested in interacting with more successful research faculty, a finding that is consistent with the "star scientist" papers on 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 the university is not reaping 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 applied in nature.[8] Such an applied focus for research may not resonate well with many faculty members.

Hall, Link, and Scott (2003, p. 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

[8] 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.

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 may want to encourage its more accomplished faculty members to participate in such internal processes. It appears that many faculty members are circumventing the technology transfer office. Universities also encourage faculty to seek external research support. Our findings imply that when they are successful, they are more likely to attempt to commercialize the results of their research directly with industry.

If our interpretation is correct, universities should be rethinking aspects of their technology transfer policies and procedures. Many universities are focusing their faculty hiring efforts on academic 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 should 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.

Table 1
Descriptive Statistics (n=766)

Variable	**Mean**	**Standard Deviation**
COMMERC	.305	.461
JOINTPUB	.281	.450
CONSULT	.349	.477
GENDER	.509	.500
TENURE	.739	.440
GRANTRES	.252	.146
Biology	.033	.178
Computer Science	.091	.288
Mathematics	.020	.139
Physics	.030	.171
Earth and Atmospheric Science	.052	.223
Chemistry	.072	.258
Agriculture	.110	.313
Chemical Engineering	.112	.316
Civil Engineering	.152	.360
Electrical Engineering	.097	.296
Mechanical Engineering	.138	.346
Materials Engineering	.093	.291

Table 2
Probit Estimates from Equation (1)
(standard errors in parentheses, n=766)

	Dependent Variable		
Independent Variable	***COMMERC***	***JOINTPUB***	***CONSULT***
GENDER	0.264	0.103	0.438
	(.099)*	(.098)	(.097)*
TENURE	0.205	0.204	0.342
	(.115)***	(.114)***	(.113)*
GRANTRES	0.616	0.679	0.006
	(.285)**	(.287)**	(.268)
Log Likelihood	-445.6	-446.6	-476.1

Notes: Discipline effects are held constant. Probit results are weighted by discipline sampling proportions.
* = significant at .01 level; ** = significant at .05 level; *** significant at .10 level.

Table 3
Probit Estimates from Equation (1) with Alternative Measure of Tenure
(standard errors in parentheses, n=747)

	Dependent Variable		
Independent Variable	***COMMERC***	***JOINTPUB***	***CONSULT***
GENDER	0.234	0.077	0.364
	(.105)**	(.105)	(.103)*
YRSTENURE	0.089	0.071	0.120
	(.041)**	(.040)***	(.040)*
GRANTRES	0.656	0.767	0.158
	(.258)**	(.294)*	(.276)
Log Likelihood	-433.2	-434.9	-464.1

Notes: Discipline effects are held constant. Probit results are weighted by discipline sampling proportions. * = significant at .01 level; ** = significant at .05 level; *** significant at .10 level. Also, 19 faculty did not report the year that they received tenure, thus reducing the size of this sample to 747,

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