# To Patent or Not: Faculty Decisions and Institutional Success at Technology Transfer

Jason Owen-Smith[1]
Walter W. Powell[2]

ABSTRACT. We draw on qualitative data derived from field work on two university campuses to develop an explanation for widely disparate rates of new invention disclosure. We argue that faculty decisions to disclose are shaped by their perceptions of the benefits of patent protection. These incentives to disclose are magnified or minimized by the perceived costs of interacting with technology transfer offices and licensing professionals. Finally, faculty considerations of the costs and benefits of disclosure are colored by institutional environments that are supportive or oppositional to the simultaneous pursuit of academic and commercial endeavors.

**JEL Classification:** L33, M13, M14, O31, O32, and O34

## 1. Introduction

The last two decades have witnessed a sea-change in relationships between universities, industry, and the federal government. Beginning in the early 1980s, key federal policy changes enabled small businesses, public and nonprofit organizations, including universities, to hold title to intellectual property (IP) developed during the pursuit of federally sponsored research and development (R & D). Since then, research universities have developed increasingly close ties to the world of commerce. Through licensing and other forms of technology transfer, strategic alliances, and spin-off firms, universities have become a driving force in the development of high technology industries (Saxenian, 1994; Rosengrant and Lampe, 1992; Powell, 1998) and regional economic development (Feldman and Florida, 1994).

Against this backdrop of broad change, institutional prestige for research universities is increasingly defined in terms of both academic and commercial science (Owen-Smith, forthcoming; Powell and Owen-Smith, 1998). Nevertheless, both the process and the success rate for transferring high quality basic science into commercial development varies greatly across U.S. research universities. At some institutions, high profile basic science moves into the commercial realm with few missteps and delays, resulting in healthy revenue streams, close and productive relationships with industry, and broad intellectual property portfolios. In contrast, other campuses with strong basic research programs have floundered in their efforts to commercialize scientific discoveries.

We argue that these differential outcomes are steeped in distinctive institutional contexts that shape the transfer of knowledge from public sources to private firms. On most university campuses, technology transfer offices (TTOs) mediate the interface between university and industry, through procedures and work practices designed to enact university IP and technology transfer policies. In university environments a crucial first step for technology transfer is to convince faculty to disclose their potentially valuable innovations to TTOs.

Most TTOs lack the resources and competencies necessary to search a wide range of laboratories and research groups for commercially viable technologies. Thus, institutional success at patenting depends in part on faculty perceptions of the benefits of patenting, the quality of the TTO, and the institution as a collective enterprise. Faculty

[1] *Stanford University*
*509 CERAS Bldg.*
*Stanford, CA 94305-3084*
*E-mail: jdos@stanford.edu*
[2] *Stanford University*
*509 CERAS Bldg.*
*Stanford, CA 94305-3084*

*Journal of Technology Transfer, 26, 99–114, 2001*
*© 2001 Kluwer Academic Publishers. Manufactured in The Netherlands.*

decisions to disclose, then, are shaped by the mixture of individual incentives, local organizational procedures, and institutional milieus. The meanings academic researchers attach to IP and their perceptions of the local patent process color decisions to disclose potentially valuable innovations within the context of a university's history, environment, capacity, and reputation. We draw on 68 semi-structured interviews on two campuses to begin unraveling the effects of distinctive institutional environments on university technology transfer success, focusing empirically on faculty accounts of their decisions to patent.

We begin by introducing the two university cases, pausing briefly to discuss the logic supporting their selection, sampling, and interview methods. We then focus on the institutions' distinct capacities for conducting science and engineering research. This comparison highlights the differential rates of commercial success on the two campuses and examines several possible explanations for the divergence. We suggest that, regardless of important organizational and capacity differences, institutional environments that catalyze or inhibit academic patenting play a large role in explaining the varied outcomes. We then turn to a discussion of faculty perceptions of the positive outcomes of patenting, demonstrating that on both campuses accounts vary significantly by research area. While the perceived benefits of patenting are very similar at both campuses, disclosure rates vary widely at the two schools. Faculty decisions to pursue patents on new technologies are based on perceived benefits of IP protection, but those perceptions appear to be shaped by (a) concerns about the local patenting process and TTO, (b) conceptions of the larger institutional environment in which academic patenting occurs, and (c) perceptions of the potential pecuniary returns to patenting which are themselves forged by institutional histories and environments.

## 2. Introducing the cases, EPU & BSU

Elite Private University (EPU) and Big State University (BSU) represent two extremes in the pursuit of patents and patent revenue. EPU combines first rank academic science with a highly successful technology transfer and licensing operation. In contrast, BSU has been less able to transform its high quality basic science portfolio, which excels in the areas of optics, atmospheric science, and cancer research, into commercial success. Table I presents a detailed comparison of EPU and BSU in terms of institutional characteristics, technology transfer infrastructure, R&D capacity, scientific reputation, and commercial success.[1]

Note first the wide disparities between EPU and BSU on all measures of technology transfer activity. EPU faculty disclosed nearly 3 times more than BSU faculty in 1998, and filed more than 8 times the new patent applications. In terms of success, EPU inventors were issued five times the number of patents issued to BSU inventors and EPU received a whopping 128 times more (gross) royalty income. The picture is clearly one of widely disparate commercial outcomes. The first step in empirically examining the sources of these disparities is to explain the gap in faculty propensity to disclose new technologies.

Table I also indicates that EPU and BSU differ in terms of technology transfer capacity. EPU's Technology Licensing Office (TLO) is nearly 20 years older and more than nine times larger than BSU's Technology Transfer Office (TTO). The institutions also differ on measures of academic prestige. EPU ranks higher than BSU on three measures of scientific reputation: National Research Council faculty quality ranking (maximum = 5), a standardized measure of publication impact, and the percentage of faculty holding prestigious (and peer reviewed) NIH or NSF grants.

But despite the wide gulf between the institutions on these measures of reputation, technology transfer capacity and accomplishment, the campuses are rather similar in terms of aggregate research capacity. EPU and BSU are within one standard deviation[2] in terms of number of active researchers, total R&D expenditures, and publication volume. Put differently, relative to Research One universities, these two schools have very similar numbers of science and engineering researchers,[3] spend approximately the same amount of money on R&D, and publish a similar number of science and engineering journal articles. While the institutions differ on several dimensions, both are conducting approximately the same volume of science and engineering research.

The aggregate comparisons highlighted in Table I suggest two explanations for the campuses' differential rates of commercial accomplishment. EPU has both more experience and capacity to pursue patents and license technologies and 'better' science on which to base that pursuit than does BSU. Consider the disaggregated measures of research capacity presented in Table I. These numbers indicate important differences in capacity concentration across the campuses. There are significant differences in the location of EPU and BSU's respective research competencies. While both institutions are accomplished in terms of overall capacity and quality, EPU's capabilities in the key areas of life sciences and engineering are noticeably more developed

Table I
Case comparisons: EPU v. BSU

| | EPU | BSU |
|---|---|---|
| Institutional characteristics | | |
| Institutional control | Private | Public |
| Land grant? | No | Yes |
| Medical school? | Yes | Yes |
| Agricultural school? | No | Yes |
| Total enrollment (1998) | 15,000 | 35,000 |
| S&E grad enrollment (1998) | 4,600 | 3,200 |
| S&E post-docs (1998) | 1,100 | 500 |
| Faculty size (1996) | 850 | 1,350 |
| Endowment assets (1996) | > $3 Billion | < $100 Million |
| # Research doctorate programs (1993) | > 40 | < 30 |
| Research capacity | | |
| Total researchers (1998) | 6,540 | 5,040 |
| Total R&D expenditures in thousands (1998) | 410,309 | 302,328 |
| Total articles published (1998) | 3,795 | 2,426 |
| Life science researchers (1998) | 1,545 | 1,523 |
| Life science R&D expenditures (1998) | 155,050 | 75,275 |
| Life science articles published (1998) | 807 | 475 |
| Physical science researchers (1998) | 429 | 587 |
| Physical science R&D expenditures (1998) | 58,555 | 71,248 |
| Physical science articles published (1998) | 629 | 576 |
| Engineering researchers (1998) | 2,629 | 732 |
| Engineering R&D expenditures (1998) | 116,364 | 42,394 |
| Engineering articles published (1998) | 741 | 431 |
| Tech transfer capacity | | |
| Formal TTO? | Yes | Yes |
| Patent management firm? | No | Yes |
| Foundation/corporation? | No | No |
| Licensing FTEs (1998) | 18 | 2.5 |
| Support FTEs (1998) | 5.5 | 4.5 |
| Program founded | 1970 | 1988 |
| Tech transfer measures | | |
| # Disclosures (1998) | 247 | 90 |
| # New applications (1998) | 130 | 16 |
| Issued patents (1998) | 86 | 17 |
| Issued patents (1976–1998) | 889 | 72 |
| New licenses/options executed (1998) | 118 | 32 |
| Licenses yeilding income (1998) | 299 | 45 |
| Gross licensing income (1998) | 61,245 | 477 |
| # Start-ups formed (1998) | 9 | 3 |
| # Licenses with equity (1998) | 6 | 0 |

than BSU's. Across the academic universe, engineering and biomedical research are the two main drivers of patenting (Owen-Smith, 2000).

Consider, for instance, the disparities apparent across engineering faculty on the two campuses. EPU has three times more active engineering researchers, spends nearly 3 times more on engineering R&D, and produces nearly double the engineering publications that BSU does. A similar pattern obtains across most of the key research areas highlighted in Table I. The same holds true for academic prestige as measured by NRC quality rankings, publication impact, and rates of success in federal grant competitions. Table I tells us that EPU's particular constellation of disciplinary strengths in science and engineering is highly suited to a program of aggressive commercialization. In contrast, at BSU the most prestigious researchers cluster primarily in such areas as astronomy, atmospheric science, archaeology, and management information systems,[4] which are less likely to develop patentable innovations. Thus, even aggressive approaches to patenting by the university may meet with more limited success.

Table I suggests a set of institutional explanations for the divergence in disclosure rates. The TLO at EPU has both the experience and resources to devote more thoughtful effort to searching for new inventors and they are likely to be more successful than BSU has. EPU has more researchers and more resources dedicated to research in areas likely to produce inventions than does BSU and a greater volume of research results in more patentable discoveries. In addition to dedicating more resources to research in key areas, the quality of research conducted at EPU is considered higher than that conducted at BSU, and 'better' science is more likely to result in patentable discoveries. We consider each of these explanations (which we dub the patent capacity, research capacity, and research quality explanations respectively) in turn, arguing that while these differences *are* important, they do not entirely account for the huge gap in disclosure rates across the campuses.

*Patent capacity*

The TLO at EPU is better funded and staffed than BSU's TTO, but interviews in both offices suggest that neither dedicates much time and resources to pursuing new disclosures. In both offices, licensing professionals primarily evaluate unsolicited submissions. In rare cases, licensing professionals (LPs) on each campus report that 'word of mouth' referrals led to the discovery of a new faculty inventor, as in these comments by two staff members in the TLO.

> We do not actively seek out disclosures because we do not really need to. Now, having said that, you form certain networks. For instance, I got a call about a year ago from one of my established inventors who I have good rapport with. He said, you should go out and talk to this person, he is a new faculty person from Harvard and he is doing some interesting things. So I went over and talked to him. I introduced myself and learned about some of his research results and then I suggested to him that he might wish to fill out an invention disclosure on them. I am not sure, had I not gone over and chatted with him, whether he would have thought to do that. *Physical Sciences LP*, *EPU*

> We really have not had to do that [actively solicit] because most of the people know that we are here. The active inventors know that we are here and if they do not know we are here then one of their colleagues does. A lot of times their colleagues will say hey you need to contact the TLO or they will call us with a referral. *Life Sciences LP*, *EPU*

Notice that neither comment suggests returns to direct searches for new disclosures. Rather, the comments highlight the importance of internal network contacts, office visibility, and campus-wide reputation in determining disclosure rates.

Licensing staff do not actively search for new disclosures for several reasons. Both the TLO and TTO's resources are already strained by managing active IP licenses and evaluating unsolicited invention disclosures. The death of a physical sciences staff member in the TTO at BSU left a single full time professional responsible for evaluating *all* new disclosures. These circumstances kept most physical sciences disclosures from being considered for nearly a year. While the TLO's workload is not as overwhelming, staff there report caseloads ranging from 60 to about 400 active "dockets." No one in either office spends their scarce time searching for extra disclosures under these conditions.

In addition to resource constraints, most licensing professionals lack the expertise necessary to identify potentially patentable technologies across the wide range of disciplines represented by university inventors. Only one staff member in the TLO is Ph.D. trained in science or engineering. While every licensing professional at BSU is Ph.D. trained in a science or engineering field the small staff mitigates against active solicitation of disclosures. Even though individual licensing professionals at BSU have more technical and professional expertise than the average staff member in the TLO, scarce time and resources mitigate against turning this expertise to active solicitation of disclosures.

The TTO's acting director at BSU holds a Ph.D. in chemistry and comes to the office from a background in industrial research and university licensing. He notes that while it might be possible to 'solicit' new inventions, time and staffing constraints at the university mitigate against such searches.

> With all the time in the world I could walk up to the chemistry building and walk up and down the halls and say hey what are you doing. You know, if we had all the time in the world that would be worth doing. I do stimulate a large number of inventions because I sit down and work with people regularly in one area and you are chatting and you hear something and say oh gee, that sounds like it's really a new invention, have you disclosed? So I have solicited in that sense, in the sense of discussion with people. But the people that I discuss with are typically those that have already disclosed, and these may be new inventions by the same people rather than going around knocking on doors and talking to new people. Although I have occasionally done that, it is lower on the priority list so I have not done it often.

These comments explicitly emphasize time and staffing constraints while implicitly suggesting the difficulties inherent in searching for technologies outside of the discipline in which one is trained. This LP would feel confident walking up and down the halls of the chemistry building because of his training and research background but, in addition to his duties as acting director, he is responsible for evaluating and marketing all life sciences disclosures on campus. So he must work in many fields outside his own expertise, which further mitigates against active search efforts.

Increased technology transfer capacity in the form of experience and staff would certainly assist in the evaluation and marketing of new technologies. Even though there is some evidence of returns to scale in licensing revenue (Siegel, Waldman and Link, 1999), a similar relationship does not appear to hold for faculty disclosures. At EPU and BSU more staff do not result directly in more disclosures because neither the TLO nor the TTO devotes time and effort to active solicitation of disclosures. Instead of seeing direct returns to scale in terms of disclosures, we expect that increased staff and experience will yield indirect returns by coordinating the patent process and raising the positive visibility of patenting on campus. Increased technology transfer capacity at EPU, then, does not provide a complete explanation of the disclosure gap, absent a consideration of faculty's reasons for disclosing.

### *Research capacity*

EPU's research capacity is concentrated in areas likely to yield patentable findings. Consequently EPU faculty should discover more potentially valuable technologies than do their colleagues at BSU. Nevertheless, at issue is not the number of potentially valuable discoveries but the number of *disclosures* of such discoveries to university offices responsible for patenting and licensing. We contend that the step from invention to disclosure is a problematic one for faculty and that decisions about whether to pursue patent protection are colored by the incentives and costs associated with patenting in specific university contexts. Under this conception, research capacity is a necessary but not sufficient condition for disclosures. While EPU's higher disclosure rate may result from its greater capability, the relationship should, as with the link between patent capacity and disclosures, be mediated by faculty perceptions of the costs and benefits of patenting.

### *Research quality*

A final explanation suggested by Table I – that the higher profile research conducted at EPU will pay off in more potentially patentable technologies and thus more disclosures than the lower profile research conducted at BSU – elides the distinction between discovery and disclosure in the same manner as the research capacity explanation. Nevertheless, differences in scientific prestige do account for some disparities in disclosure rates (Owen-Smith, 2000).

In the life sciences, high prestige research and patent productivity increasingly go hand in hand (Powell and Owen-Smith, 1998; Blumenthal *et al.*, 1996). Indeed, investigations of the role that 'star' scientists play in biotechnology innovation (Zucker, Darby and Brewer, 1998; Zucker and Darby, 1996; Audretsch and Stephan, 1996) suggest that formal and informal linkages between academic scientists and local firms promote such innovation. The configuration of EPU's high prestige scientists and engineers and their location in a thriving high technology region foster entrepreneurial activity. Moreover, local firms may seek out highly visible scientists and engineers.

By virtue of their physical location and higher prestige, EPU scientists are more likely to be contacted by firms and engaged in commercial research than their colleagues at BSU. Clearly this commercial involvement raises inventor awareness of the value of intellectual property. But does greater awareness lead EPU scientists to disclose inventions to their university? Recent examinations of university technology transfer (Siegel *et al.*, 2000) and our own findings suggest that dissatisfaction with university patent processes may lead faculty inventors to circumvent technology transfer offices by engaging in 'informal' technology transfer through consulting activities or by leaving the academy. The key step in successful tech transfer is creating an entrepreneurial culture among the faculty. Without it, enterprising faculty might well take their IP outside the university. The important step is getting faculty to disclose their inventions to the university and sharing the revenues with the campus at large.

If commercial involvement accompanies higher prestige science, then, in the absence of an institutional environment supportive of both commercial and basic science activities, high quality science may lead to fewer invention disclosures as scientists capitalize on greater contacts with firms to transfer technologies without the knowledge or involvement of their institutions. There are many such efforts to circumvent the university process on both campuses. Physical scientists and engineers at EPU commonly assign title to patents developed during consulting agreements to the firms who hired them. Software and new media projects often rely on copyright rather than patent protection to escape revenue sharing with the university. Some computer programs are released with open source code, allowing faculty to spin-off service companies without assigning title to the university. Finally, graduate students interested in starting up firms occasionally file incomplete dissertations to maintain their sole ownership of IP developed during graduate school.

At BSU, informants among faculty and in the TTO report shirking on the part of faculty inventors who write incomplete or early stage disclosures in order to have inventions released by the university so they can be pursued independently. In order to facilitate independent pursuit of patent protection, a group of BSU life scientists has founded a small company whose primary purpose is to commercialize inventions released by the TTO. Here again, we contend that the relationship between scientific prestige and invention disclosures is mediated by the effects of local processes and campus environments on faculty decisions to disclose.

Despite the fact that BSU's scientific reputation does not rise to the level of EPU's, it is consistently one of the most prestigious and well funded public research universities and appears in the top quartile of *all* Research One (R1) institutions. Thus, we think it is accurate to argue that while EPU does "better" science than BSU, *both* institutions rank among the most prestigious and productive American universities. While we might expect BSU to trail EPU in commercializing research findings, we suspect that BSU should be accomplishing more than it has been. BSU lags far behind its public peer institutions in terms of patenting and licensing success, ranking in the bottom quartile of R1 institutions in terms of disclosures, patent volume, licenses, and royalty income.

Across R1 institutions commercial success and academic accomplishment are not consistently related (Owen-Smith, 2000). Consider three public universities; Iowa State, Michigan State, and the University of Florida. The former two rank among the top ten patenting universities in 1998, the latter ranks in the top fifteen (Owen-Smith, 2000). Two of these institutions (Florida and Michigan State) ranked among the top ten revenue earners in 1998 (Association of University Technology Managers, 1998). But all three institutions rank in the bottom quartile in terms of academic visibility as measured by citation impact (Owen-Smith, 2000).

The wide disparity in disclosure rates across the campuses is, in our view, not simply the direct result of capacity or prestige differences. Rather, the institutions' differential success at inducing faculty to disclose potentially valuable inventions depends upon the creation of an institutional environment that supports faculty perceptions of the benefits of patenting while minimizing conflicts between commercial and basic science activities. Thus, faculty propensity to disclose is shaped at three analytic levels. One, individual scientists' perceptions of the professional and personal benefits of IP protection generate incentives to disclose. Two, such incentives are magnified or weakened by the ease of the local patent process and inventors' perceptions of the competence and facility of technology transfer offices. Three, the technology transfer process and capacity on each campus is shaped by the unique histories and environments that characterize each institution.

The last two factors depend, in large part, on the work done in technology transfer offices. In our view, one reason that EPU has been able to capitalize on its elite endowment of capacity and talent while BSU has been less successful at transforming its high quality basic research portfolio has to do with the creation and maintenance of an institutional environment supportive of both commercial and academic science and enabling of multiple uses of IP.

We support our claims with data drawn from 68 semi-structured interviews with faculty, licensing professionals, and research administrators on the two campuses. Field work was conducted in Fall, 1999 and Spring, 2000. Twelve physical scientists, twelve life scientists and eleven licensing professionals were interviewed during this time period at EPU. At BSU, 33 interviews with fifteen life scientists, eleven physical scientists and seven LPs or attorneys were conducted. Interviews ranged from 45 minutes to nearly three hours in length and were guided by a protocol of 25 questions. Subject sampling was guided by compiling lists of the most prolific patentors on each campus from patent archives. We then turned to snowball sampling techniques to identify other inventors and notable scientists who chose not to patent at each institution.

## 3. Why do faculty patent?

We turn to an extended discussion of academic inventors' reasons for patenting to establish two important findings relevant to the explanation of different disclosure rates at EPU and BSU. First, we demonstrate that the incentives that lead faculty to patent vary significantly across general research areas. We argue that this variance helps explain disclosure rates by suggesting that universities that create processes and environments conducive to multiple uses of IP will maximize disclosures by engaging a broad range of faculty. Second, we determine that faculty perceptions of patent benefits (incentives) do not vary across our cases. EPU and BSU, then, do not have different disclosure rates because faculty are responding to different incentives to disclose. Instead, we argue, similar perceptions of patent benefits are colored by widely disparate local processes and institutional environments resulting in different disclosure rates.

Inventors' responses to two interview questions ("Why do you patent your findings?" and "How do you decide which findings to patent?") reveal that faculty account for their decisions in terms of (1) perceptions of the personal and professional benefits of patenting, (2) perceptions of the time and resource costs of interacting with TTOs, and (3) their general opinions about the campus environment for technology transfer. Scientists' accounts of their decisions to disclose innovations and pursue patents varied across research areas. The director of EPU's TLO captured these differences succinctly when she said, "Physical scientists patent for freedom of action, life scientists patent for strategic advantage." Put differently, life science inventions have a larger potential to open new markets where gaining value from intellectual property will not be constrained by existing products or patents. In contrast, physical sciences inventions, for instance new techniques for magnetic resonance imaging, often enter crowded markets where established products and intellectual property hamper organizations' abilities to gain revenue from IP.

The upshot of this claim is that physical scientists, whose inventions are typically improvements on established processes or products, will use patents to develop relationships with firms and as chips to exchange for the use of other proprietary technology, access to equipment, or other opportunities. In keeping with this more relational approach, physical scientists should (1) expect less direct personal gain from patent royalties, (2) favor non-exclusive licensing arrangements, and (3) be less concerned with finding the "right" licensee, opting instead to open relationships with multiple corporate partners.

The inventions of life scientists commonly involve therapeutic compounds or medical devices. If they are seeking strategic advantage for these novel entities, then these faculty should view patents more as tangible properties to be protected and sold. Rather than using patents to establish relationships with multiple partners, then, these scientists will be concerned with finding the best partner to develop and market a drug or device. In keeping with this more proprietary approach to IP, life scientists should (1) expect personal gains from patent royalties, (2) favor exclusive licensing arrangements, and (3) be concerned with defending IP.

These general patterns hold true in faculty responses to our interview questions. Comments made by physical and life scientists highlight these general differences.

> Our goal is to transfer the technology to industry, it is to build relationships with companies, it is to educate students. That is what we are about. We are not about making money. The money is the tool with which you conduct relationships with the outside world. You need some value that you place on your negotiations so that you arrive at an optimum point. *Senior Physical Scientist*, *EPU*[5]

> I have to disclose when we think [an invention] might have value. We happen to work on a lot of things that have to do with behaviors and diseases. We do not want to take any chances that we might miss something. So, we just put a disclosure in. Most of them will not make any difference to tell you the truth, but if you miss the golden egg − you might only get a few in your life. Fortunately, we have a few golden eggs. The university could get multi-million dollars from [X technology] and it could get multi-million dollars from [Y technology] at some point in the future. *Senior Life Scientist*, *BSU*.

These comments underscore general differences between relational and proprietary approaches to patenting. Note that both these inventors are concerned with outcomes of patent protection − leverage and relationship building in the former case, protection and income in the latter. Conceptions of the benefits of patent protection vary with research areas. These variations result in different motivations to disclose innovations and pursue patents.

*Patenting outcomes vary by research area*

Table II summarizes beliefs about patent outcomes highlighted by physical and life scientists' accounts of their decisions to disclose. The first column presents general types of outcomes mentioned by EPU and BSU faculty. Both life and physical scientists talked about the value patents have as protection, leverage, and sources of income. Both groups also discussed the intangible benefits of patenting. Interestingly, their accounts of what these outcomes meant varied significantly.

Consider, for instance, the first row of Table II that highlights physical and life scientists' understandings of patent protection in terms of limiting constraints on action and protecting academic freedom. Despite the apparent similarity of these concerns, researchers seem to mean very different things when using protection as a reason to disclose.

> You can go out and tell people things and sign an agreement, what's called a non-disclosure agreement, to try and protect yourself. In recent years, one of the stratagems has been to get … what is called a provisional patent that gives you a year to try it out on the market… . Suppose I am doing some research and I want to go to your conference and talk about it. One doesn't want to be restricted by this darn patent business. It [a provisional patent] is not too expensive. *Senior Physical Scientist*, *EPU*

> It is complicated because one of the issues is that if EPU holds a patent that governs the use of a gene they are not going to enforce it in a way that interferes with academic research, whereas a private company might. So there is some incentive to disclose to EPU just to protect academic freedom … It is certainly an issue in my mind that an incentive to patent is because if someone else were to file a patent on [a gene] that conflicts that could really impair your research or impair academic freedom … I think that I would do just about everything possible to undermine the commercial companies who want to patent just about everything. *Senior Life Scientist*, *EPU*

Both of these comments imply that patent protection enables freedom of action but for the first

Table II
Physical and life scientist's perceptions of patent outcomes

| Outcome | Physical | Life |
|---|---|---|
| Protection | limits restraints on communication | protects academic freedom from commercially held patents |
| | enables commercialization | enables commercialization/required for drug development |
| | limits actions of foreign competitors | keeps findings from being 'robbed' |
| | | keeps faculty from being 'skinned' by firms |
| | | keeps faculty from missing 'the golden egg' of a very valuable property |
| Leverage | enables requests for funds from deans, department chairs | helps convince firms to pay for development research 'beyond the NIH track' |
| | leads to consulting, sponsored research, and student jobs industry | enables faculty to locate venture capital funding |
| | aids in obtaining federal grants by leveraging 'cutting edge' equipment from firms | |
| Money | getting rich | getting rich |
| Intangibles | curiosity | serving the public good |
| | validation of research | fighting disease |
| | increased prestige | increased prestige |
| | helps forward 'basic science' thinking | helps forward 'basic science' thinking |
| Education | helps students get jobs | |
| | reading/writing patents and negotiating relationships is essential training | |

scientist that freedom is public, involving the ability to go to conferences and present findings without being restricted by fear of losing potentially valuable property rights. Autonomy also extends to the freedom to market a finding to figure out if it is worth pursuing. In this case, patenting increases freedom by establishing IP protection for the faculty member.

Compare this with the second view. To this life scientist the protections afforded by patenting are not enabling of public presentations of work. Instead, his reasons for pursuing IP protection represent a form of constraint. By undermining the expansive agenda of a potentially aggressive commercial firm he removes their ability to control a key resource, information, and ensures his freedom to conduct research without external restraints. While both scientists express concerns with commercial constraints, the first wishes to maintain the potential value of his technology while trying it out on the market and advertising it at professional meetings. The second scientist expresses no concern about the value of his technology; instead, he is interested in shielding the private environment of his lab from encroachment by commercial interests. In the end, two very different types of protection are achieved by the same mechanism.

Similar differences are apparent in faculty discussions of the leverage afforded by patents. Note that physical scientists believe patents provide leverage at multiple levels, within the university, in relationships with firms, and in federal grant competitions. Life scientists are more concerned with patents as a means to attract investments in their research from firms and venture capitalists. The life-scientists' image is less one of building a relationship than of capital infusion.

The acting director of the TTO at BSU summarizes incentives for physical scientists to patent in terms of the long run benefits of licensing relationships.

> The main [incentive to disclose] is the one I mentioned, we share income with the faculty. That is the upside. The

> downside is that it is required. Faculty are state employees. Their inventions are state property and they are required as state employees to disclose. So that is the carrot and the stick. Plus the fact that licensing, in addition to personal income, can lead to grant and contract funding, and to sponsored research. Most licenses require further information for corporate development and I encourage the company to support faculty research and to continue working with faculty research teams. That is another reason to disclose.

Contrast this view of the benefits of patent based relationships with the more proprietary approach of a senior life scientist at EPU.

> One of the best ways to get leverage on industry is to have some property. Then you have something to sell, you have something to negotiate. I'm really a firm believer in that … Because if you want to turn around and start a company or if we want to go to a company and say hey we need a million bucks to take our research to the next phase because it looks too applied to fly through a study section, or if we need a lot more money than an NIH study section would realistically look at for a grant, we would have very little to go on without a patent application or an issued patent. But if you go to the same pharmaceutical company or venture capitalist and say I have an issued patent, then things would look a lot different.

Just as was the case with protection, faculty accounts of the leverage afforded by IP vary widely depending on research area. Similar incentives to disclose patentable technologies are framed very differently by life and physical scientists, but these differences are common across at least two university campuses.

Where protection, leverage, and personal income represent tangible incentives to patent in the form of freedom, negotiating power, and money, a fourth category of patenting outcomes discussed by faculty is much more elusive. Both physical and life scientists highlight intangible personal benefits of patenting. Across research areas many faculty agree that there are status benefits to patenting. Both groups also note that the intellectual exercise of patenting a finding opens new realms of basic science investigation.

Positive relationships between typical academic activities and patenting also result from the view that patenting aids in the development of basic science research programs. A junior physical scientist at BSU emphasizes the scientific benefits of patenting:

> If I try to go into a new research area and try to make a broader scientific impact, I will ask myself some of the questions I would ask when I evaluate an invention. It also helps in the process of analyzing some types of data. When you start thinking in terms of claims for patents you say I got that result, how can I broaden that claim's impact? So if you ask yourself these questions in terms of your research it gives you immediate new experiments that you need to perform because now you can say I have learned this in that context and that impacts other fields. Then you ask is this new and unexpected? If the answer is yes, we try to initiate experiments looking for principles, for new concepts. So that thinking actually has helped me be more creative in my research.

This comment suggests that the exercise of patenting can actually forward academic research agendas. While there is some disagreement about the relationship between patenting and academic prestige, many inventors reveal that they patent, in part, because they feel it increases their academic visibility and status by reaffirming the novelty and usefulness of their work. In so doing, patenting and commercial activities can reinforce traditional, status based, academic reward structures.

By connecting commercial and academic reward structures, patenting and its varied benefits can have a positive effect on the pursuit of traditional academic rewards. In other words, through protection, leverage, and intangible intellectual and status benefits, commercial activities can help scientists forward their academic accomplishments. Scientists are loathe to relinquish academic benefits for pecuniary returns (Stern, 1999), so mutually supportive linkages between commercial and academic activities should increase disclosure rates.

Faculty decisions to disclose are driven by their perceptions of the potential outcomes and benefits of patenting. In accounts of why they patent, life and physical science faculty highlight the same general types of benefits, but with respect to two important consequences − protection and leverage − their comments suggest divergent understandings and uses of patenting.

## 4. Perceptions of local policies color patent benefits

There is interesting variation in physical and life scientists' accounts of why they patent. But faculty perception of potential gains do not vary widely between EPU and BSU. Clearly, something other than perceptions of the benefits of IP protection is effecting faculty decisions to disclose on the two campuses. We argue that similar benefits of patent protection are differently colored by faculty beliefs about the costs of pursuing IP through their respective universities.

At EPU, where perceptions of the TLO and its staff are generally high and where a history of spectacular success contributes to an air of optimism, the benefits of patenting discussed above lead more faculty to disclose inventions. In contrast, at BSU, where perceptions of the TTO are generally low and there is no track record of success, faculty who are not already committed to pursuing IP may weigh the potential benefits of inventorship against the potential frustrations of the process and opt out by refusing to disclose new inventions.

A senior EPU life scientist who has patented a technology that is potentially very valuable captures this tradeoff in his discussion of the TLO:

> The people in my group and I, number one, do not want to get bogged down too much in the mechanics of filing the patent. Also, I would say that most of us, certainly including me, are uneasy about the idea of patenting … Basically, I would just say that when I have the time on my hands and I feel that I can actually deal with the mechanics of it, and I feel like there is something that really has significant commercial potential, then I generally disclose it to the TLO…. If I thought that disclosing something would result in a month's work drafting a patent application, helping them with licensing or anything like that, I don't think they would ever hear a word from me.

Levels of faculty involvement with the patent process run the gamut on both campuses. Several inventors draft entire applications (two EPU faculty are themselves patent agents) while others prefer to avoid the process and cannot even identify the number of patents issued to them. But the comments of scientists who feel uneasy about the entire endeavor are key to understanding differential disclosure rates. On both campuses, the most commercially inclined faculty will pursue intellectual property regardless of perceptions of the process. As an EPU licensing associate noted, "If they [faculty] really want to be involved [in commercialization] they will disclose whatever the office does." With faculty who are aware of their findings' commercial potential but ambivalent about patenting, a less obtrusive and burdensome process is essential to making the benefits of disclosure worth the perceived costs.

Differences in faculty perceptions of patent processes and infrastructures across the campuses provide one explanation for disparate disclosure rates. Cross-campus process differences cross-cut the physical/life sciences distinction that drives accounts of patent value. Note the striking differences in comments about the patenting process by EPU and BSU inventors.

> I have to say that the TLO does a pretty credible job of making it fairly easy, and they are very considerate. They will come out whenever you have a slot open to get the relevant information. They will do much of the paperwork and so forth for you. So I'm not sure it could get a whole lot easier. *Junior Life Scientist*, *EPU*

> In our group it is kind of a healthy atmosphere, you patent things and you never know up front how valuable they are going to be. You just don't know, but the process is pretty painless. *Junior Physical Scientist*, *EPU*

> I do not know whether it is cultural. I do know that when you submit something it is going to die. It will not leave here. So, how can you generate a revenue stream if it never leaves the campus? *Senior Physical Scientist*, *BSU*

> So the problems that I have had just involve getting that patent through the university… In fact, what happened is that the company [a start-up licensee] has to use its own law firm who then instructs the university's law firm about what to do. Quite honestly, it has been so bad that I probably would make an effort not to disclose things to the university unless I thought it was absolutely essential because I have little confidence in their ability to push it through. *Senior Life Scientist*, *BSU*

Widely disparate perceptions of the technology transfer process at BSU and EPU shape faculty understandings of the potential benefits of patenting. In cases like that of the scientist whose technology was licensed to his own successful start-up company, frustrations with BSU's patent process deter later disclosures even by commercially involved and successful faculty.

The universities' differential capacities and infrastructures for technology transfer play an important role in explaining disclosure rates. A large and experienced office at EPU enables flexible responses to faculty schedules, relatively quick turn-around, the development of long term relationships with inventors, and the creation of specialty teams who work to address the divergent concerns of life and physical scientists. In contrast, BSU's underfunded and understaffed office is blamed for long delays, inconvenient schedules, lax reporting, and minimal responsiveness to the concerns of academic inventors.

While process failures are partially responsible for BSU's relative lack of invention disclosures, it is important to note that both the difficulties and faculty responses to them do not arise in a vacuum. BSU is a public institution, it is responsible to a broader range of stakeholders than EPU, and is hampered by less flexible policies on intellectual property ownership and technology transfer (Siegel *et al*., 1999). The problematic relationship between the TTO and faculty inventors at BSU points to larger challenges faced by public research universities. As was suggested by the TTO's acting director, faculty are regarded as State employees first, and entrepreneurs to be assisted by the TTO second. By the same token, faculty inventions are unequivocally regarded as State property.

A smaller staff of licensing professionals has less time to cultivate relationships with faculty. And their lack of success has meant increasing pressure from the State legislature and university governing body to justify their existence. As a result of the need to develop revenue earning properties, the attention of the staff is directed toward landing a blockbuster revenue generating patent.

At nearly all campuses, a small number of patents generate the bulk of the revenue stream (Association of University Technology Managers, 1998). For instance, at Florida State, which falls in the bottom quartile of R1 institutions in terms of patent volume, a blockbuster patent on the use of Taxol as a cancer therapeutic accounts for the lion's share of the revenues which place FSU among the top five royalty earning universities. Hence, BSU's focus on a big hit success is not unreasonable. Indeed, BSU's ex Vice President for Research opines that

> With a couple of exceptions, Columbia being one and MIT being another among the privates, among the publics, most people that make a lot money make it predominantly on one patent. They get lucky. OK, we have not gotten lucky yet… Now I mean in principle we could come up with some blockbuster thing in electronics or optics, but we have not. The pharmaceuticals are where the greatest opportunities and markets are and we have a lot of strength in that area.

This administrator's comments emphasize the importance of big hit patents for developing royalty streams, while explaining BSU's focus on developing a blockbuster in the life sciences.

By virtue of differences between life and physical science approaches to patenting, searching for a blockbuster means emphasizing life sciences innovations at the expense of physical sciences properties and their long term relationship generating benefits. This focus on landing a blockbuster and negotiating the most lucrative licensing deal minimizes the leverage benefits of patenting, alienates physical scientists who feel that their disclosures receive short shrift, and slows the daily operations of the patent process. Our point is that a sole focus on a big success hinders efforts at cultivating high quality researchers who have been hesitant to disclose and patent.

As a consequence of this focus, routine and timely processing of patent applications are delayed, deadlines are missed, and negotiations drag on. In short, a cycle is created where chasing a "bit-hit," under considerable legislative and administrative pressure, creates less productive relationships between faculty and LPs. In turn, the failure to pursue smaller scale "bread and butter" disclosures limits future chances for commercial success by encouraging faculty to bypass the TTO or avoid commercial activities altogether.

## 5. The environment for entrepreneurial science

We have shown that EPU and BSU faculty account for their decisions to patent by appeal to the outcomes and benefits of IP protection. Perceptions of patent outcomes vary across life and physical scientists. Moreover, variations in the ease and effectiveness of patent processes and technology transfer offices influence faculty thinking about the personal and professional benefits of patenting. The interaction of perceived benefits and potential frustrations, we contend, helps account for some of the differences in disclosure rates across the campuses. But both faculty perceptions and institutional capabilities combine to have broader consequences. Patenting and its outcomes are framed by faculty in terms of a larger institutional environment encompassing peer support of patenting, the effects of prior success, campus wide awareness of commercial activity, and the degree of overlap between commercial and academic science.

We draw on responses to the question: 'Why has (hasn't) EPU/BSU been (more) successful at commercialization?' to highlight the core features of an institutional environment which can be either supportive or oppositional to academic patenting. Against this broader background, faculty conceptions of the patent process and patent outcomes interact to create and maintain distinctive contexts for commercial science.

The catch-all phrase "entrepreneurial culture" is central in informants' explanations of EPU's commercial success. Discussions of a broad campus culture supportive of patenting are almost entirely lacking in interviews conducted at BSU. Entrepreneurial culture has been used to explain the success of high-technology regional economies and has been adopted by faculty and administrators to explain the success of highly commercial universities. A strong culture of patenting attracts faculty interested in pursuing commercial endeavors and socializes new university members into that pursuit. In this kind of environment, status becomes attached to commercial outcomes and technology transfer endeavors come to reinforce traditional academic status hierarchies, linking tangible and intangible patent benefits together with ongoing academic pursuits by blurring the boundaries between commercial and academic science.

The director of EPU's successful TLO describes the effects of an entrepreneurial culture on the university:

> I think there is an entrepreneurial culture out here. I guess my feeling is that since the eighties, since I have been at EPU, you can just see that culture among the faculty. Now it has moved down to the students. They say well I am smarter than so and so and so and so has made millions. I think we all know people who have done really well with equity. So I think that it is now inbred, the competition that is going on.... I think that in the region there is some kind of competition where if you have started a company or if something came of your invention there would be prestige associated with that... It is definitely a risk taking culture.

These comments capture all of the themes present in faculty discussions of a supportive entrepreneurial culture: (1) the effects of success; (2) publicity and widespread awareness of success; (3) a supportive peer environment; and (4) status benefits ascribed to commercial accomplishments. In contrast, a senior physical scientist at BSU suggests that the very things that characterize EPU's entrepreneurial culture are missing at his institution.

> Commercial success would change the culture, making that part of our research plan. I suppose that to do that we would really have to change our way of thinking about the relative value of patenting to us. I think it would take something really dramatic in that area to change our thinking about the value of patenting...

In short, success begets success and a lack of achievement can be difficult to overcome even when high quality science is present. Indeed, evidence drawn from the BSU case suggests that pursuing some types of commercial success may actually hinder attempts at commercial development on other parts of the campus and may even slow the progress of more academic investigations. A history of success, on the other hand, leads to continued accomplishment by raising awareness, changing the way faculty think about patenting, and reinforcing the tangible and intangible benefits of IP protection. In our view, two key environmental factors will contribute to decisions to disclose despite frustrations with local processes: (1) widespread awareness of patenting procedures and benefits, and (2) publicity about success. EPU and BSU are separated on both these dimensions.

In order for faculty inventors to evaluate the benefits of patent protection or the costs of filing an application they must be aware of the activity. When faculty whose research is potentially valuable are unaware of procedures for or outcomes of IP protection, disclosures will naturally be lower than on campuses where a supportive institutional environment ensures a high level of commercial awareness among potential inventors. Consider the implications of two quotes from interviews with senior life scientists. The first comes from a BSU faculty member who has never disclosed an invention, even though his neurobiological work on a model species of moth that is a notorious crop pest has many potential applications.

> For people like me awareness of patenting is essentially zero. I probably know less about that than I do about Medieval European social history. Really, that happens to

> be something that I am interested in. There is no information provided here, no advice urged upon us. If we wanted to do anything about this we would have to be very highly motivated to go out and seek the information, get the advice. We would have to, I think, be more sophisticated than most of us are – than I certainly am – to know when to do that or what sort of thing should trigger it.

Contrast these comments with the thoughts of an EPU faculty member whose patented technologies form the core of a new start-up firm. The BSU faculty member describes an environment where low commercial awareness require "sophistication" and "motivation" on the part of commercially interested faculty members. In contrast, this EPU life scientist paints a picture of an environment buzzing with commercial activity where choosing not to patent would be "rare indeed."

> I think this is an extraordinary place because you have so many people in the peer group or reference group who are running around inventing things, often with NIH money, and going to the technology licensing office asking them to put the capital up to file an invention disclosure and getting first rate patent lawyer to write the patent. Then, after it is done, the university owns the property but they take the strong and, I think, logical position that disembodied technology is relatively worthless. So they usually accede to the wishes of the inventor... I think that faculty members deciding not to patent would be rare indeed here at EPU. Even if you were so inclined it would be hard to ignore how fabulously successful some of your peers are. You know, from the kind of cars they park in the parking lot and your children might be interacting with their children and say hey dad, why does Joe have all of this while we're living in a thatched roof hut? It would just be astonishing not to notice.

These comments describe an institutional environment, shaped by EPU's history and location, supportive of commercial activity that extends beyond the campus into parking lots, local schools, and Little League fields. In such an environment the benefits of patenting will be magnified as commercial successes yield prestige among academic peers and enable inventors to leverage resources for their ongoing academic projects. Under these conditions, tangible and intangible incentives to disclose are magnified by low costs to patenting and an environment which links commercial endeavors with academic success. In contrast, on a campus like BSU where a high level of motivation and sophistication is required even to enter the commercial arena, and the costs of patenting are high and unconnected to academic success, patent benefits will be minimized, resulting in fewer decisions to disclose.

## 6. Conclusions and implications

Our aim has been to use the differences in disclosure rates at BSU and EPU as a first step toward unraveling the effects of policy and context on universities' commercial accomplishments. Because technology transfer offices generally lack the resources and expertise necessary to search for potentially valuable innovations, the first step toward success for an institution interested in commercializing science is to convince often ambivalent faculty to disclose new technologies to the university.

Drawing on qualitative data from interviews with 68 faculty and licensing professionals on two Research One campuses, we suggest that faculty decide to patent because of their beliefs about the positive personal and professional outcomes of establishing IP protection. While all faculty mention similar incentives to patent, their understanding of two key benefits, protection and leverage, vary between life and physical sciences research areas. Where life scientists on these campuses focus more on the proprietary benefits of patents as commodities, physical scientists tend to emphasize the relational benefits of patents as markers for exchange.

Faculty beliefs about patent benefits vary by research area, but they do not vary across our university cases. Divergent perceptions of patent benefits cannot explain the different disclosure rates at EPU and BSU. Instead, we argue that the decision to disclose a new finding on these campuses depends upon conceptions of the patent benefits, framed by the costs of interacting with licensing professionals and technology transfer offices.

On each campus, the most commercially oriented faculty are likely to transfer technologies regardless of the costs involved. But inconvenient or frustrating interactions with TTOs may be enough to convince ambivalent inventors that the benefits of IP protection do not outweigh the costs. Process and infrastructure difficulties may recalibrate incentives to disclose. Thus, similarly perceived patenting outcomes are enacted in faculty decisions differently on the two campuses because of widely disparate beliefs about the efficacy of each university's technology transfer office.

Ambivalence about patenting may lead to failure to disclose when the costs of commercial engagement are high. Nevertheless, the distinctive institutional environment in which commercial activities are embedded will color faculty perceptions of both patent benefits and costs. We identify several themes in faculty descriptions of their campus environments: (1) widespread awareness of success and patent benefits, (2) supportive (or perhaps competitive) peer environments, and (3) the ascription of academic status to commercial success. These are three of the factors that contribute to an institutional environment conducive to the simultaneous pursuit of basic and commercial science at EPU. All three factors are absent at BSU where commercial and academic activities remain in opposition. As was the case with beliefs about patent costs, faculty perceptions of their institutional context color decisions about whether to disclose.

Where faculty are highly aware of other's successes, prestige is associated with commercial success. When academic and commercial rewards are linked, incentives to patent are enhanced. In this kind of setting, frustrations with the patent process may be overcome by the general positive reputation of the multiple benefits of IP protection and even ambivalent inventors may begin to disclose. In environments where commercial and academic success remain separate, faculty who wish to patent may be discouraged by their surrounding environment and high costs of pursuing protection through a technology transfer office that is hampered by the need to chase one type of commercial success. On campuses like these, we contend, only the most commercially oriented faculty will seek to disclose new findings and frustrations with the costs of disclosure may drive even those inventors to seek other means of transferring technology.

## Acknowledgements

The authors wish to thank the researchers and licensing professionals who took the time to share their experiences and opinions on university technology transfer. We also thank Janet Bercovitz, Don Siegel and the participants at the Purdue University conference on Organizational Issues in University Technology Transfer for their careful and helpful comments on early versions of this paper. This research was supported by a grant from the Association for Institutional Research (AIR # 99-129-0, Jason Owen-Smith P.I.), and by NSF grant # 9710729 (W.W. Powell and K.W. Koput, Co-PIs).

## Notes

1. Some figures in Table I have been rounded to preserve the institutions' anonymity and protect informant confidentiality. In addition pseudonyms have been assigned to institutions and individuals are identified only by general research area and rank.
2. For Research One universities.
3. Faculty, research staff, post-docs, and graduate students.
4. BSU's exceptional optics program is a notable exception.
5. In the interests of maintaining informant confidentiality we classify individuals in terms of seniority (associate professor and above = senior) and general research area.

## References

Association of University Technology Managers, Inc., 1998, *AUTM Licensing Survey*, *Fiscal Year*.

Audretsch, D.B. and P.E. Stephan, 1996, 'Company-Scientist Locational Links: The Case of Biotechnology', *American Economic Review* **86** (2), 641–652.

Blumenthal, D., E.G. Campbell, N. Causino, and K.S. Louis, 1996, 'Participation of life-science faculty in research relationships with industry', *New England Journal of Medicine* **335** (23), 1734–1739.

Feldman, M. and F. Richard, 1994, 'The Geographic Sources of Innovation: Technological Infrastructure and Product Innovation in the United States', *Annals of the Association of American Geographers* **84** (2), 210–229.

Nelson, R., 1993, *National innovation systems: a comparative analysis*, New York: Oxford University Press.

Owen-Smith, J., forthcoming, 'New Arenas for University Competition: Stratification in Academic Patenting', in Jennifer Croissant (ed.), *University Industry Research Relations*, New York: SUNY Press.

Owen-Smith, J., 2000, *Public Science*, *Private Science: The Causes and Consequences of Patenting by Research One Universities*. Ph.D. Dissertation, University of Arizona.

Powell, W.W. and J. Owen-Smith, 1998, 'Universities and the market for intellectual property in the life sciences', *Journal of Policy Analysis and Management* **17** (2), 253–277.

Powell, W.W., 1998, 'Learning from collaboration: Knowledge and networks in the biotechnology and pharmaceutical industries', *California Management Review* **40** (3), 228–263.

Saxenian, A., 1994, *Regional advantage: culture and competition in Silicon Valley and Route 128*, Cambridge, Mass.: Harvard University Press.

Siegel, D., D. Waldman, and A. Link, 1999, 'Assessing the Impact of Organizational Practices on the Productivity of University Technology Transfer Offices: an Exploratory Study', NBER Working paper W7256.

Siegel, D., D. Waldman, L. Atwater, and A. Link, 2000, 'Transferring Scientific Knowledge from Academicians to Practitioners: Qualitative Evidence from the Commercialization of University Technology Transfer Offices', unpublished manuscript.

Stern, S., 1999, 'Do Scientists Pay to be Scientists?' NBER Working paper #7410.

Zucker, L.G. and M.R. Darby, 1996, 'Star Scientists and Institutional Transformation: Patterns of Invention and Innovation in the Formation of the U.S. Biotechnology Industry', *Proceedings of the National Academy of Science* **93** (23), 709–716.

Zucker, L.G., M.R. Darby, and M.B. Brewer, 1998, 'Intellectual Human Capital and the Birth of U.S. Biotechnology Enterprises', *American Economic Review* **88** (1), 290–306.