

Commercial knowledge transfers from universities to firms: improving the effectiveness of university-industry collaboration.

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Abstract:

There has been a rapid rise in commercial knowledge transfers from universities to practitioners or university–industry technology transfer (UITT), through licensing agreements, research joint ventures, and start-ups. The purpose of this study was to analyze the UITT process and its outcomes. Based on 98 structured interviews of key UITT stakeholders (i.e., university administrators, academic and industry scientists, business managers, and entrepreneurs) at five research universities in two regions of the US, we conclude that these stakeholders have different perspectives on the desired outputs of UITT. More importantly, numerous barriers to effective UITT were identified, including culture clashes, bureaucratic inflexibility, poorly designed reward systems, and ineffective management of university technology transfer offices (TTOs). Based on this qualitative evidence, we provide numerous recommendations for improving the UITT process.

Keywords: commercial knowledge transfers | technology management | technology management research | effectiveness | university/industry collaboration

Article:

1. Introduction

In the 1970s, American universities were criticized for being more adept at developing new technologies than moving them into private sector applications (US General Accounting Office, 1998). Policymakers asserted that the long lag between the discovery of new knowledge at the university and its use by companies was seriously impairing the global competitiveness of American firms in such key industries as steel, automobiles, televisions, and semiconductors (Marshall, 1985). In 1980, Congress attempted to remove potential obstacles to university to industry technology transfer (UITT) through legislation, which became known as the Bayh–Dole

Act (Feldman, Link, & Siegel, 2002). Bayh–Dole instituted a uniform patent policy across federal agencies, removed the restrictions on licensing, and allowed universities to own the patents that arise from federal research grants. Presumably, these changes would give universities greater flexibility in negotiating licensing agreements, and firms would be more willing to engage in them. The framers of this legislation asserted that university ownership and management of intellectual property would accelerate the commercialization of new technologies and promote economic development and entrepreneurial activity.

It appears that Bayh–Dole has indeed brought research universities closer to practitioners and entrepreneurs seeking to commercialize university-based technologies (Jensen & Thursby, 2001). In the aftermath of this legislation, many universities established technology transfer offices (henceforth, TTOs) to manage and protect their intellectual property. The role of the TTO (sometimes referred to as the Technology Licensing Office) is to facilitate commercial knowledge transfers (or technological diffusion) through the licensing to industry of inventions or other forms of intellectual property resulting from university research. There has been an impressive rise in UITT activity, as evidenced by an increase in the number of patents granted to US universities from about 300 in 1980 to approximately 3700 in 1999 and a threefold increase in licensing of university-based technologies to firms since 1991. Annual streams of revenue accruing from these licenses have risen from about US\$160 million in 1991 to US\$862 million in 1999, now constituting about 2.8% of university R&D expenditures. More importantly, numerous products in a wide variety of key strategic high-technology industries (e.g., computers, pharmaceuticals, agriculture, biotechnology, and instruments) have been developed through UITT. These include internet search engines (e.g., Lycos), the Boyer–Cohen “gene-splicing” technique that launched the biotechnology industry, CAT scanners, diagnostic tests for breast cancer and osteoporosis, music synthesizers, computer-aided design (CAD), and environmentally friendly technologies (US General Accounting Office, 1998).

Despite the potential importance of UITT as a source of financial gain to universities and firms and as an engine of economic growth, there is little systematic understanding of organizational practices in the management of university intellectual property. Furthermore, little attention has been paid to the managerial or private sector implications of UITT. Given that the stakeholders in this process of knowledge transfer (e.g., university faculty, university administrators, private sector managers) have different motives and behaviors and operate in different environments, there is room for considerable disagreement and misunderstanding about the UITT process and how it should be managed. Nevertheless, the “boundaryless organization” philosophy driving change at firms such as General Electric argues for eliminating boundaries vertically down hierarchies, as well as horizontally across departments (Ashkenas, Ulrich, Jick, & Kerr, 1995). Moreover, boundaries between a firm and its customers or suppliers (e.g., universities) should be reduced. In this paper, we present reasons why such boundaries exist between universities and firms and prescribe methods for making such boundaries more seamless.

Thus, the primary goal of this paper is to improve our understanding of UITT so that the managers of the process in universities and industry can enhance its effectiveness. We provide a number of recommendations based on a series of 55 interviews we conducted with 98 UITT stakeholders at five research universities in two regions of the US. These stakeholders included university scientists and administrators, industry scientists, R&D managers at large companies, and entrepreneurs.

The remainder of this paper is organized as follows. In the next section, we analyze the UITT process and examine the goals, motives, and cultures of its major stakeholders. This is followed by an in-depth description of our qualitative methods. We then summarize the field evidence and identify the key outputs of UITT, as well as organizational barriers to the effectiveness of the process. Next, we provide recommendations for technology managers at universities and firms regarding ways to enhance the effectiveness of commercial knowledge transfers between universities and firms. The final section consists of conclusions and reflections on UITT in the 21st century.

2. The UITT process

2.1. Technology transfer in a university setting

Technology transfer is usually thought of as occurring within or across firms, such as the dissemination of information through transfers of employees from one division or country to another (intra-firm transfers of technology). Indeed, much research has focused specifically on the flow of technology transfer within a large R&D organization, or from an R&D subunit to the larger organization (Allen, 1984). In this paper, we focus instead on the UITT process, or commercial transfers of scientific knowledge from universities to firms.

We contend that the key stakeholders in UITT are: (1) university scientists, who discover new technologies, (2) university technology managers and administrators, who serve as liaisons between academic scientists and industry and manage the university's intellectual property, and (3) firms/entrepreneurs, who commercialize university-based technologies. This is by no means an exhaustive list of stakeholders. For example, the federal government, which funds most of these research projects, can also be viewed as a stakeholder.

A general flow model of UITT and stakeholder involvement is shown in Fig. 1. It begins with a discovery by a university scientist in a laboratory or other university setting. The scientist then files an invention disclosure with the TTO. At this point, university officials must decide whether to patent the innovation, in order to protect their intellectual property. This is a somewhat costly decision, so the TTO must evaluate the potential for commercialization. Often, interest in the technology by an industry partner provides sufficient justification for filing a patent. In other cases, the TTO must make a judgement prior to interest being expressed by industry. This is not a trivial decision, since most universities have limited budgets to devote to the filing of patents, which can be quite expensive if the school seeks global patent protection. Schools may choose to apply for domestic patent protection, which safeguards the technology at a much lower cost.

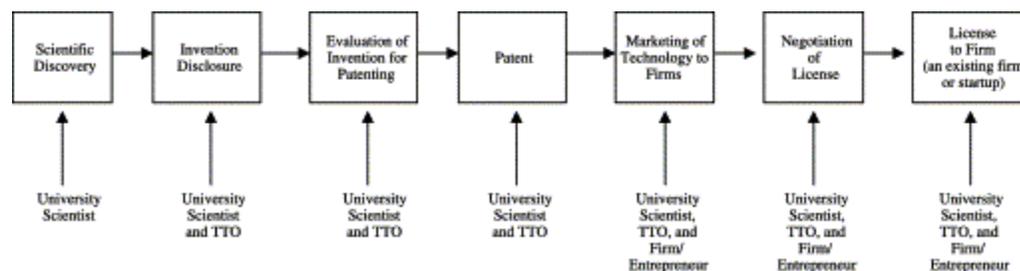


Fig. 1. How a technology is transferred from a university to a firm or entrepreneur (according to theory).

Once the patent has been awarded, the TTO can market the technology, sometimes with faculty input. That is, faculty members can be involved in the process of identifying potential corporate licensees. The next stage involves working with private firms or entrepreneurs (i.e., in the case of start-up firms) to negotiate a licensing agreement for the intellectual property. The agreement could include such benefits to the university as royalty allowances and an equity stake in the case of start-ups. In the fifth and final stage, the technology is converted into a commercialized product. The university may continue its involvement with the firm, for instance, by devoting resources to the maintenance of licensing agreements. Moreover, in the case of start-ups, faculty members may serve as technical advisors or on boards of directors and may also have an equity stake in the start-up.

2.2. Motivation of key stakeholders

A significant aspect of UITT involves the consideration of the actions, motives, and perspectives of scientists, university administrators, and firm/entrepreneurs, which we present in Table 1. A primary motive of university scientists is recognition within the scientific community, which typically emanates from publications in top-tier journals, presentations at prestigious conferences, and research grants. Faculty members may also be motivated by personal financial gain and/or a desire to secure additional funding for graduate students and laboratory equipment.

Table 1. Key stakeholders in the transfer of technology from universities to the private sector

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Perspective
University scientist	discovery of new knowledge	recognition within the scientific community—publications, grants (especially if untenured)	financial gain and a desire to secure additional research funding (mainly for graduate students and lab equipment)	scientific
Technology transfer office	works with faculty members and firms/entrepreneurs to structure deals	protect and market the university's intellectual property	facilitate technological diffusion and secure additional research funding	bureaucratic
Firm/entrepreneur	commercializes new technology	financial gain	maintain control of proprietary technologies	organic/entrepreneurial

The primary motive of the TTO and university administration is to safeguard the university's intellectual property, while at the same time market that intellectual property to firms. Secondary motives include securing additional research funding for the university via royalties and licensing fees, sponsored research agreements, and an intrinsic desire to promote technological diffusion (the goal of the Bayh–Dole Act). TTO managers, like other university administrators, work within the bureaucratic framework of the university.

The actions and motives of firms and entrepreneurs are relatively straightforward (Siegel, Waldman, & Link, 1999). They seek to commercialize university-based technologies for financial gain. To do so, they desire exclusive rights to the technologies that are generated. Firms and entrepreneurs also express great concern about “time to market,” since the ultimate benefits from product and process innovation depend on commercializing the product or perfecting the new production process before competitors do. Finally, firms and entrepreneurs are also concerned about maintaining proprietary control over technologies.

Differences in the actions, motives, and perspectives of the three key players in this process underscore the potential importance of organizational factors in effective university management of intellectual property. One key goal of our field research was to explore these differences so that we could identify a set of organizational and managerial policies and practices to overcome critical barriers to effective technology transfer. In addition, although Bayh–Dole and much of the existing literature stresses commercialization of university-based technologies as the predominant outcome (e.g., licensing and start-up formation) (Bercovitz, Feldman, Feller, & Burton, 2001), we also sought to ascertain how each stakeholder group defines the outputs of UITT.

3. Method

Our results and recommendations are based on semi-structured, in-person interviews with three categories of UITT stakeholders: (1) TTO directors and university administrators, (2) academic scientists, and (3) managers/entrepreneurs. We focused our analysis on five major public and private research universities in Arizona and North Carolina. These universities have relationships with many large and small firms and have also spawned a number of start-up companies. Each of these schools established a TTO soon after the enactment of Bayh–Dole in 1980. Note that we did not examine hotbeds of technology-transfer activity, such as Cambridge/Boston (MIT, Harvard, and Boston University) or the San Francisco Bay area (Stanford and UC—Berkeley). However, the schools we visited are probably far more representative of the average university experience with technology transfer than top-tier schools that have the most favorable environments for stimulating this activity (the best graduate students, an abundance of available venture capital, and a strong entrepreneurial culture). Recall also that the policy initiative, the Bayh–Dole Act, was designed to stimulate UITT at all research universities, not just top-tier institutions.

At each university, we interviewed academic scientists who have transferred technologies, the TTO director, and at least one administrator who oversees the TTO, usually a Vice Provost, Vice President, or Vice Chancellor for Research. Within the surrounding region of the university, we also interviewed founders of start-up companies, directors of business development, intellectual property managers and other research managers at large companies, and executives of patent management firms and nonprofit organizations with an interest in UITT.

Potential respondents were identified from two sources of information. First, we identified the TTO director and consulted each university's organizational chart in the research area to identify the administrator(s) to whom the TTO director reports. Second, to identify managers/entrepreneurs and scientists, we solicited feedback from two organizations that serve as technology-transfer "facilitators" in each region. By design, these organizations have a balanced view on technology issues. That is, they do not favor one stakeholder group over another. Because facilitators are well connected to many firms, TTOs, and administrators, we used them to identify managers and scientists who had a wide variety of perspectives on UITT and many relationships with TTOs.

In Arizona, we interacted with the High-Technology Industry Cluster (HTIC) of the Governor's Strategic Partnership for Economic Development (GSPED). HTIC includes small and large businesses and has a technology transfer committee, consisting of members who have had both positive and negative experiences with various universities. Thus, we selected members of HTIC to interview, rather than ask university TTOs for a list of firms to contact. In North Carolina, we relied on the North Carolina Biotechnology Center (NCBC) and the Research Triangle Institute (RTI), which are both nonpartisan organizations that provide advice to academics and firms who wish to transfer technologies. NCBC and RTI were also capable of providing connections to individuals and organizations with a broad range of views on UITT.

In sum, a stratified approach was used for the selection of interviewees, so that interviewees would be drawn from the three UITT stakeholder groups. We conducted 55 interviews: 20 managers/entrepreneurs, 15 university administrators (5 TTO directors and 10 other top-level administrators), and 20 university scientists. Our sample included a mix of large and small companies and faculty members in a wide variety of academic disciplines (physics, biology, chemistry, medicine, pharmacology, and engineering). Although there were only 55 face-to-face meetings, we actually interviewed 98 individuals, since more than one person was present at some meetings.

The interviews consisted of a series of open-ended questions that were designed to determine how various stakeholders defined technology transfer and its outputs as well as what they viewed as impediments to successful technology transfer and strategies for improvement. A list of the interview questions used for each group is presented in Appendix A. Note that each stakeholder group was asked to define technology transfer and its outputs, identify impediments to successful technology transfer, and to provide suggestions for improving the process. Questions varied slightly depending on the type of interviewee. For example, only TTO directors and other university administrators were asked to comment on the managerial practices of the TTO. On

average, the interviews lasted approximately 1 h and were tape recorded with the consent of interviewees. A typist was hired to transcribe the tapes, in order to ensure a complete and unbiased recording of the interview data.

In order to conduct a quantitative analysis of the qualitative interview data, we employed procedures outlined in Miles and Huberman (1994). First, we simplified and transformed the raw data into an analyzable form, using an initial list of general categories for content analysis purposes. All comments were then independently categorized by two members of the research team into four areas: (1) the nature of UITT outputs, (2) UITT networks and relationships, (3) barriers to UITT, and (4) proposed improvements to the UITT process. The two researchers' lists of comments within a topic area were then compared, and discrepancies were discussed between the two researchers until agreement was reached regarding comments that were pertinent to each category. Similar methods were employed by Butterfield, Trevino, and Ball (1996), who identified unique “thought units” pertinent to their subject of interest (employee discipline).

After a consensus was reached regarding the categories, we returned to the lists of comments pertinent to the each of the four general categories and sorted them into the themes identified for that respective category. For data display purposes, we tabulated the frequencies with which comments emerged for each theme by stakeholder group. For example, Table 2 presents the percentage of respondents who identified themes relevant to barriers to UITT by stakeholder group.

Table 2. Stakeholder perceptions of the barriers to university-industry technology transfer (UITT)

Barriers	Type of stakeholder		
	(1) Managers/entrepreneurs	(2) TTO directors/administrators	(3) University scientists
Lack of understanding regarding university, corporate, or scientific norms and environments	90.0	93.3	75.0
Insufficient rewards for university researchers	31.6	60.0	70.0
Bureaucracy and inflexibility of university administrators	80.0	6.6	70.0

Barriers	Type of stakeholder		
	(1) Managers/entrepreneurs	(2) TTO directors/administrators	(3) University scientists
Insufficient resources devoted to technology transfer by universities	31.6	53.3	20.0
Poor marketing/technical/negotiation skills of TTOs	55.0	13.3	25.0
University too aggressive in exercising intellectual property rights	80.0	13.3	25.0
Faculty members/administrators have unrealistic expectations regarding the value of their technologies	25.0	40.0	10.0
“Public domain” mentality of universities	40.0	8.3	5.0
Number of interviews	20	15	20

The values presented in columns (1)-(3) are the percentages of respondents who identified a particular item as a barrier to UITT.

4. Results and recommendations

In this section, we present our qualitative results regarding stakeholder perceptions on various aspects of UITT. Based on these perceptions and our understanding of how management theories can be applied to UITT, we provide some recommendations for university-based and firm-based improvements in the effectiveness of UITT.

Our interviews revealed that the outputs most frequently mentioned by TTO directors and university administrators were licenses and royalties, which is not surprising since they generate revenue for the university. To a somewhat lesser extent, university administrators also identified patents and sponsored research agreement as outputs of UITT. Although managers and entrepreneurs identified licenses as an output, they also mentioned broader notions of output, such as product development, profit, and economic development. One manager stated:

For us in business, it [technology transfer] means that we use some of this technology to generate profits for our shareholders. But more importantly, there's a social return which results from the economic development, creation of jobs, the hiring of graduate students.

Indeed, the most frequently mentioned UITT output by managers and entrepreneurs was informal transfer of know-how. An illustrative comment by a manager was:

So much of what we call technology transfer is information transfer, knowledge transfer. It's not something that could be put immediately into a product. It might be something that is a tidbit of knowledge that will help somebody in their development efforts at one of our companies.

Some university scientists most frequently identified product development and licenses as outputs, although many were reluctant to think of the process in terms of generating "output." They tended to see UITT more as a continuous process rather than one with specific outcomes. Their responses resembled those of UITT managers in that informal transfer of know-how was seen as an output. Our interpretation of this finding is that they could not reach a consensus on the outputs of UITT because they are too focused on their own role in this process and fail to see the "big picture." In this regard, we present the following phrases mentioned by scientists in their discussions of outputs:

training the engineers who are going to be working with industry

patents that will be in my name and the graduate students' names

working with graduate students who are subsequently hired by firms

We also solicited information from stakeholders regarding barriers to effective UITT. All three groups identified a lack of understanding regarding university/corporate/scientific norms as a pervasive barrier to effective UITT. That is, business managers asserted that university scientists and administrators do not understand or appreciate industry goals/culture/constraints, while university scientists and administrators believe that industry does not understand or appreciate university goals/culture/constraints. Representative comments from university administrators

tended to point the finger toward the business community and their lack of appreciation for the university's role and processes:

Industry has a lack of understanding of what an academic institution does and a lack of understanding of what a university faculty member's responsibility is to their institution. There are some companies I don't even deal with because their approach to dealing with an academic entity is so poor. They feel that basically, we owe them by our position at the university because the state pays our salaries.

They say to us, you've got all that technology over on the shelf, why aren't you getting it out to the marketplace? They don't understand what we mean by technology. We don't have technology in little boxes on shelves that people can pull out and apply. They think it is like the warehouse at the end of Indiana Jones.

University administrators also questioned the sophistication of university scientists' understanding of the process. In referring to his own faculty members, one university administrator stated:

Some faculty members have a purely academic orientation and don't have a lot of interest in dealing with private companies...or they don't understand what the motivations of private companies are.

The managers/entrepreneurs in our study commonly perceived that universities are too aggressive in exercising intellectual property rights. This results in a hard line on negotiations, excess concern on the part of university administrators that they will not realize sufficient revenue, and unrealistic expectations. A typical comment was:

I think the frustration for commercial licensees who go to a university is that it seems as though the attitude they are hitting at the university is 'oh we've got this wonderful thing and we're going to drag every nickel out of you that we can get for it'.

A manager of a biotechnology firm provided this example:

University scientists look at a technology, maybe it's a petri dish compound that kills fast-dividing cells. Now they can make an extrapolation to an anticancer drug. They look at the market for anticancer drugs and see that they are billions of dollars a year. Therefore, their invention must be worth billions of dollars. When you tell them it's only worth a few hundred thousand dollars they don't understand it is because of the stage of development...all the risk in going forward and whether it really works.

Managers/entrepreneurs and university scientists frequently cited university bureaucracy and inflexibility as barriers to UITT. Essentially, they believe that universities wish to follow rigid procedures that may not fit a particular situation. Furthermore, they noted that these procedures are cumbersome and often not clearly specified. A typical remark from a scientist was:

I don't think they [the TTO] understand the flexibility within the framework and what they can do. I think they have a set of forms and a set of ways of doing things and if it doesn't fit nicely into that, then you know they make you to through a whole bunch of hoops.

A manager provided this example:

A lot of technology transfer office people just know what the book says about what the value of this should be commercially, but they don't realize that the value to any given licensee of a very early technology is not what the book says.

University administrators and scientists also cited insufficient rewards for university researchers who are engaged in technology-transfer activities as a barrier to effective UITT. In essence, all groups acknowledged that with few exceptions, university promotion and tenure practices did not value technology transfer. One exception was in engineering, where there was some recognition of this activity. However, the vast majority of interviewees noted that promotion and tenure decisions are based exclusively on publications and federal research grants, with no weight placed on patents and industry partnerships.

Finally, with regard to barriers to technology transfer, firms and entrepreneurs were inclined to point out that the marketing, technical, and negotiation skills of the TTO could be substantially improved. Comments from firms/entrepreneurs included:

What it takes to be a successful technology transfer officer is being a dealmaker, not an academic.

These guys [TTOs] need to be marketing facilitators rather than lawyers. They need to be able to step into the company and into their customer's shoes and look back.

Similarly, a scientist remarked:

In a TTO, they have to know the field. They have to know where they think the technology is moving and then be able to make a decision whether or not to file these patents.

A university administrator also acknowledged:

The impediment to successful technology transfer at this university was a lack of marketing and skill within the technology transfer office.

In sum, these comments demonstrate the existence of many barriers to effective UITT, including culture clashes, bureaucratic inflexibility, poorly designed reward systems, and ineffective management of TTOs. The end result is a failure to maximize opportunities to transfer technologies, which hurts universities, firms, and ultimately, consumers. In order to avoid such problems in the future, we provide suggestions for improving the UITT process.

The results from the interviews suggest some avenues for improving UITT processes. Many of the interviewees' suggestions for improvement were extremely rich and vivid, given the strong feelings respondents have regarding UITT issues. The consensus that emerged across stakeholder

groups regarding suggested improvements was actually quite striking. Although most suggestions were aimed toward universities and their management of the process, a number of comments were also targeted at the private sector. We will divide our below discussion accordingly.

4.1. Recommendations for university-based improvements

Our recommendations for university-based improvements are presented in the top panel of Table 3, which we now consider in turn. The qualitative results suggest that universities need to improve their understanding of the needs of their true “customers,” i.e., firms that can potentially commercialize their technologies. Over 75% of all managers, TTO directors, and university scientists agreed that achieving better mutual understanding between universities and industry was needed. While there is strong evidence of cultural misunderstanding on both sides, it appears that much of the onus lies with universities and academics. One manager stated:

If I could wave a magic wand over an inventor, I would want them to understand some of the issues I have talked about before. Why does someone want to commercialize your invention? Do you really have a product? What is your goal and how do you want to reach it?

Table 3. Suggested university and firm-based improvements to the UITT process

<i>Suggested university-based improvements to the UITT process</i>
◆ Universities need to improve their understanding of the needs of their true “customers,” i.e., firms that can potentially commercialize their technologies
◆ Adopt a more flexible stance in negotiating technology-transfer agreements and streamline UITT policies and procedures
◆ Hire licensing officers and TTO managers with more business experience
◆ Switch to incentive compensation in the TTO
◆ Hire managers/research administrators with a strategic vision, who can serve as effective boundary spanners (tie to boundary spanning literature)
◆ Devote additional resources to the TTO and patenting
◆ Increase the rewards for faculty participation in UITT by valuing patents and licenses in promotion and tenure decisions and allowing faculty members to keep a larger share of licensing revenue (as opposed to their department or university)
◆ Recognize the value of personal relationships and social networks, involving scientists, graduate students,

and alumni
<i>Suggested firm-based improvements to the UITT process</i>
◆ Be proactive in their efforts to bridge the cultural gap with academia
◆ Hire technology managers with university experience
◆ Explore alternative means for tapping into UITT social networks

This manager had earlier remarked that he wished scientists and university officials could be more aware of the costs that need to go into an invention before it is marketable and that there are often “good” technologies that are commercial failures.

The mutual articulation of well-defined goals and objectives was frequently mentioned as a way to achieve an understanding of each group's values and needs and reach a common ground. One executive described goals and objectives in this manner:

There cannot be different objectives in a partnership. The company and the university in a tech transfer agreement have to say ‘this is our objective for the tech transfer.’ And they have to agree to that set of objectives. It is not sufficient for the university to say ‘well our objectives are on the publication side’ and have the company say ‘our objectives are on the profit side’ and then simply not address both objectives in the tech transfer relationship. You can have objectives that are more important to one side or the other, but they all have to be agreed upon and they all have to be worked toward.

Related to the problem of cultural misunderstanding is the need for more flexibility on the part of universities, though this suggestion came primarily from managers/entrepreneurs. Over half of them offered this suggestion. Inflexibility has a negative impact on the TTO's ability to market university-based technologies. More importantly, rigidity significantly impedes the process of negotiating a licensing agreement. Firms repeatedly expressed their frustration at the university's lack of a “deal-making” mentality and aggressive tendencies in exercising their intellectual property rights. In defense of universities, especially public ones, it is important to note that they have a legitimate fear of being accused of “giving away” a technology to a private firm. This can be a public relations nightmare for universities, especially when they are lobbying for additional funding in the state legislature.

Thus, many schools have adopted an extremely conservative negotiation stance, preferring to maximize royalties, even if this significantly reduces the probability of consummating the deal. Nevertheless, a university's risk aversion is especially frustrating for start-ups and other firms that need to respond quickly to changes in the competitive environment. Therefore, we propose that universities adopt a more flexible stance in negotiating technology-transfer agreements and that they streamline UITT policies and procedures.

We also have several recommendations relating to human resource management practices in the TTO. The need for improved marketing expertise within the TTO was commonly mentioned by the managers/entrepreneurs. Our field research revealed that TTOs usually do not actively recruit individuals with marketing skills. More often, they looked for expertise in patent law and licensing or technical expertise. A university administrator (outside of the university's TTO) suggested:

Someone should be there [in the TTO] who completely understands how to market the product. Mostly the offices are patent attorneys or negotiating attorneys...no one really comes from marketing.

Thus, universities should hire licensing officers and TTO managers with more substantial business experience.

The qualitative evidence also suggests that TTO personnel need to be effective facilitators and negotiators of UITT which means that they should engage in the types of boundary spanning roles so often described in literature on the management of technological innovation Ancona & Caldwell, 1992 and Katz & Tushman, 1983. Unfortunately, many TTOs are not actively recruiting licensing officers who possess such skills or behavioral tendencies. Several respondents who had relationships with many TTOs noted that those managed by directors with substantial business and negotiation experience had a much firmer grasp on how to assess the market potential of a particular technology and create more linkages with firms. They also had a better understanding of the complexity of negotiations and how to be flexible in order to consummate transactions. We suggest that universities should consider the business and negotiation experience of TTO personnel when making hiring decisions.

The notion that reward systems for university technology transfer should be modified was endorsed by over 80% of managers, TTO directors, and university scientists. We conjecture that one change in the rewards system that would improve the effectiveness of UITT is a switch

towards incentive compensation in the TTO. This could reduce some of the agency costs associated with university management of intellectual property. As noted in Gomez-Mejia and Balkin (1992: p. 923), “Proponents of agency theory assume that each party acts in its own self interest. This assumption gives rise to the so-called agency problem because the interests of the principal and agent may conflict.” While academic scientists receive royalties from patented technologies, TTO officers often have no direct financial incentive to spur technology transfer. That is because most licensing officers are paid strictly on salary. Perhaps if they too received some compensation from “making deals,” they would be more motivated to work on the university's behalf. Gomez-Mejia and Balkin (1992) and Eisenhardt (1988) showed that principals may successfully use incentive systems when dealing with non-programmed jobs where direct supervision or monitoring is infeasible.

A consensus also emerged on two additional suggestions for improving UITT. First, universities should devote additional resources to technology transfer and target them more effectively. Resources devoted to UITT will affect the level of patenting. Legal fees must be expended to build a valuable portfolio of university patents. This is quite expensive, especially if universities wish to file for global patent protection, which is more expensive than domestic patent protection. On a similar note, a large TTO staff may be needed to market university-based technologies effectively, especially when the reputation of the university is insufficient to draw unsolicited attention to a school's patent portfolio. That is, non-top-tier institutions must be more proactive in marketing than MIT or Stanford. One company executive summed it up this way:

It's so easy to see. You look at the TTO and see one full-time person in a 30,000-person university; there is something wrong with that picture. If they are understaffed and underbudgeted, and if there isn't a reasonable budget to protect intellectual property—you can't patent everything. That's why you need more staff.

Second, the upper administration needs to clearly articulate technology transfer as a university priority. That is, leadership is required on the part of upper administration to establish goals and priorities and espouse values pertaining to UITT. One manager of a TTO at a large public university that has achieved remarkable success in recent years underscored the importance of leadership in this quote:

The fact that our chancellor constantly stresses the importance of technology transfer as a strategic goal has really helped build support from faculty and local firms. More

importantly, the upper administration has usually backed me up when a dispute arises, which demonstrates that they are committed to this goal.

The modification of university reward systems is inherently part of establishing a UITT vision and culture. We found a widespread belief that there are insufficient rewards for faculty involvement in UITT. This is especially true for untenured faculty members, who continue to be rewarded within the university almost strictly on the basis of publications and grants. In fact, many senior faculty members look askance at junior faculty members who become involved in UITT. They allege that such activity represents time taken away from fundamental research.

Unfortunately, such reward structures can be viewed as being inconsistent with the stated organizational objective of increasing UITT, which is often advertised prominently in university mission statements and announcements to the external community. Many interviewees in all three groups specifically mentioned that technology-transfer activities should have a greater weight in faculty promotion and tenure decisions. An industry executive said:

One thing I would do at the university and I think it is being done in some...I would make a patent count toward tenure like any two papers. In fact, in some universities, they count against the researcher.

A university administrator also indicated that incentives were important:

The way to improve it [tech transfer] is to really provide the very best service you can and incentives for faculty to participate and make sure you have the information support and financial support that it is going to take for them to be successful.

It is also important to consider pecuniary rewards, such as the university's royalty and equity distribution formula. This refers to the split in licensing or equity income among the inventor(s), the department or college of the inventor(s), and the TTO or another general research fund within the university. For example, at one school we visited, the formula was 40% inventor, 40% inventor's department, and 20% "invention management fund," which is managed by the TTO. Adjusting this formula in favor of the scientists could also elicit more faculty involvement in UITT.

Finally, it is important for scientists and university administrators to realize that licenses, royalties, and patents are not the end-all-cure-all of UITT. There is also inherent value in the personal relationships and networks that include the private sector. One scientist put it this way:

I would say right now that I feel that the one-on-one interaction is somewhat more successful in effectively transferring technology [than is research sponsored by a consortium].

It appears that the formation of social networks is important in UITT processes. These networks include academic and industry scientists, and perhaps, university administrators, TTO directors, and managers/entrepreneurs Liebeskind et al., 1996 and Powell, 1990. Social networks that allow knowledge transfer appear to work in both directions. Scientists whom we 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). For example, a scientist commented:

There is no doubt that working with industry scientists has made me a better researcher. They help me refine my experiments and sometimes have a different perspective on a problem that sparks my own ideas. Also, my involvement with firms has allowed me to purchase better equipment for my lab, which helps me conduct more experiments.

The downside, from a university's perspective, is that too much informal communication between university scientists and managers or entrepreneurs in the private sector may result in a total avoidance of the TTO, i.e., fewer licenses and royalties for the university. That is, when an invention is disclosed (and thus, public information), firms may contact the scientist and arrange to work with him/her and engage in informal commercialization and knowledge transfer, through consulting or a sabbatical leave. As an example, a scientist told us that if asked to develop a piece of software for a firm he would:

probably do it as a personal consulting job rather than going through the university. Although it is probably easier for me to do it through the university, and it would probably also benefit the students more effectively, it is a hassle to do it...it is such a pain in the neck.

Another scientist reported on the attitude of firms he was working with:

In fact a lot of people will come to us and say we don't want to go through the university...we'll just pay you on the side.

However, we believe that such behavior is likely to be problematic only when university inflexibility, mentioned above, reaches such a degree that it frustrates both scientists and firms alike. Only then will university scientists attempt to circumvent more formal UITT processes. As a whole, we encourage more informal interaction between university scientists and managers/entrepreneurs in the private sector.

4.2. Recommendations for firm-based improvements

It may seem odd to propose changes in the behavior of firms/entrepreneurs, since they can be viewed as the customers of UITT, and the conventional wisdom is that the customer is always right. In addition, doesn't the university bear the ultimate responsibility for managing this process? However, we view UITT as a quintessential example of a public-private partnership. Our research suggests that if universities are to manage this partnership successfully, they require some additional input from firms. Thus, we have several suggestions for firms, which we present in the bottom panel of Table 3.

We recommend that firms be proactive in their efforts to bridge the cultural gap with academia. As previously suggested, cultural barriers are pervasive in UITT, given that stakeholders operate under diverse organizational environments and have different norms, standards, and values. For example, universities and firms differ in their perspective on the role of knowledge (Nelson, 2001). Firms typically do not want researchers to publish their results and share information with colleagues and the general public. Instead, they view technology as something to be kept proprietary and used for strategic advantage in the pursuit of profits.

Given the prominence of this difference in perspective, it is critical for companies and entrepreneurs to be make strong efforts to bridge the cultural gap. Indeed, our interviewees generated many interesting suggestions regarding ways to develop better mutual understanding, including technology expositions, formal meetings to discuss technology transfer, and conferences involving scientists, university administrators, and managers/entrepreneurs. An intellectual property manager stated:

Conferences and expos are critical in establishing relationships with scientists. I also think that the town hall meetings we have had are fruitful in reducing tensions that arise between universities and industry. I know that I have a much healthier relationship with the TTO since attending them on a regular basis.

Another executive provided this suggestion:

Our institute runs and hosts a workshop, half-day, that has been held for the last 3 years covering the Laws of Science to teach university researchers especially how to think about intellectual property.

In one state that we examined, periodic “town hall” meetings were established to help resolve controversial intellectual property rights issues and to educate firms and universities regarding each other's cultures. In the same state, the TTO director of a major research university often appears before an institutional group representing high-technology firms when intellectual property issues are being considered in the state legislature.

Another way to overcome cultural barriers is through the labor market. Several managers at large firms mentioned that they had achieved better relations with university TTOs when they hired at least one technology manager who had worked at a university or nonprofit organization. Unfortunately, many business development managers, i.e., those often serve as liaison officers between firms and universities, have little experience working with universities. That is why our second recommendation is that firms who engage in substantial UITT activity hire technology managers with university experience.

A third recommendation is that firms take advantage of all avenues to tap into UITT social networks. After all, technology transfer is frequently embodied in the transfer of human capital via graduate students, postdoctoral fellows, or a faculty member on leave or sabbatical from the university. Many entrepreneurs and managers stated that such hiring practices constituted a quite effective form of technology transfer, even though a more tangible form of UITT output, such as a licensing agreement or patent, did not emerge in the short run. In addition, industry should make greater use of these scientists and their laboratories/equipment/talent. Often, managers and entrepreneurs have ideas that can be tested with the sophisticated equipment and talent the university has to offer.

5. Conclusions

In the “new” economy, there is a stronger emphasis on intellectual property, venture capital, and entrepreneurial start-ups. The recent increase in UITT, managed through a TTO, has led to a concomitant rise in the incidence and complexity of research partnerships involving universities and firms. This has led to considerable tension and inefficiency in university management of intellectual property. That is not surprising since formal university management of a portfolio of intellectual property is a relatively new phenomenon, so we are still in a learning phase regarding “best practices.”

Our evidence suggests that there is considerable room for enhancing the effectiveness of these commercial knowledge transfers from universities to firms. We find that organizational and managerial behaviors and skills are critical factors in facilitating UITT. Specifically, universities wishing to foster commercialization need to be mindful of the following organizational and managerial factors:

- eradicating cultural and informational barriers that impede the UITT process
- designing flexible university policies on technology transfer
- improving staffing practices in the TTO
- devoting additional resources to UITT, if that is consistent with the university's mission
- enhancing the rewards for engaging in UITT
- encouraging informal relationships and social networks

More generally, our results imply that universities should consider UITT from a strategic perspective. This implies that they must address a set of formulation and implementation issues. We have already noted the critical implementation issues (e.g., changes in HRM and other organizational practices). The key formulation issues are setting institutional goals and priorities for UITT and the related issue of determining the appropriate level of resources to devote to UITT. These choices will affect decisions regarding the set of technologies (e.g., biotechnology) and modes of UITT to stress, i.e., licensing, start-ups, sponsored research, or other UITT mechanisms that are focused directly on stimulating economic development (e.g., science parks).

We have also identified some measures that firms can adopt to facilitate UITT. These include being proactive in their efforts to bridge the cultural gap with academia through frequent meetings and workshops with universities, hiring technology managers who know how to work with universities, and using the labor market to tap into UITT social networks.

US universities have long been known for their scientific breakthroughs and knowledge generation. Only through cooperative efforts with the private sector can the end result of successful commercialization materialize. It is ultimately the responsibility of both universities and firms to ensure such cooperation.

Although we have argued that there should be “thinner” boundaries between universities and firms, there are some potential problems associated with such initiatives that need to be acknowledged. Specifically, they raise concerns regarding how a shift towards commercialization at research universities affects the culture of “open science” (Poyago-Theotoky, Beath, & Siegel, 2002). Open science refers to the free exchange and dissemination of new ideas among faculty members and students. Indeed, Louis, Jones, Anderson, Blumenthal, and Campbell (2001) find that academic scientists engaged in entrepreneurial activities are more likely to deny requests from fellow academics for research results than other faculty members who are not engaged in entrepreneurial activities.

These issues are especially problematic for public universities. An example is the 1998 strategic alliance between the Department of Plant and Microbial Biology at the University of California at Berkeley and Novartis, a Swiss life sciences and pharmaceutical firm. This alliance grants first rights to Novartis to negotiate licenses on approximately one-third of the department's inventions for the next 5 years. Press and Washburn (2000) note that some faculty members and graduate students at Berkeley were concerned that Novartis would attempt to influence the department's research agenda, since the Berkeley administration permitted the company to have two of the five seats on the committee that decides how research money is spent.

Other potential concerns associated with thinner boundaries between universities and firms include a shift from basic to applied research and its influence on education Stephan (2001). For instance, collaborations with industry may shift attention away from fundamental research questions that do not appear likely to generate a commercial payoff. Others have voiced concern that faculty members involved in UITT may spend less time on teaching and service.

It is clear that universities and firms have different perspectives and goals with respect to intellectual property. As these two entities attempt to collaborate, conflicts are inevitable. However, UITT may be one process that can improve our understanding of how convergence can take place between very different organizations. For instance, our qualitative evidence suggests that, contrary to popular wisdom, technology transfer does not flow strictly in one

direction, i.e., from firms to universities. We also found that academic scientists may be able to conduct better basic research as a result of their involvement in UITT. This occurs because UITT provides them with access to better equipment and additional financial resources to conduct more experiments, as well as new ideas from industry scientists. Finally, it is conceivable that such alliances could affect the curriculum, as faculty members draw on their experiences with firms to provide instruction that is more relevant and more closely aligned with the needs of high-technology firms (Stephan, 2001).

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Appendix A. Questions asked of UITT stakeholders

Interview questions for TTO directors:

1. How do you define technology transfer? What are the outputs?
2. How has the process of technology transfer changed over time? Has the relative importance of specific outputs changed over time?
3. What data do you collect to measure the performance of your office?
4. What are the impediments to successful technology transfer?
5. How would you improve the process?
6. Could you describe your managerial philosophy? Are there any specific managerial practices that you utilize in running your office?
7. How much of your time is spent with the business community? With university scientists?
8. What is the nature of these interactions? Do you meet or talk on the phone? What issues do you discuss?

9. Who are the key individuals you network with in order to accomplish your job? What type of communication is involved in such networking? What percentage of your work time is spent in this networking activity?

10. In your role as director, how important is educating firms about the potential value of university technologies? Why do you feel it is important or unimportant?

11. Could you describe the different licensing strategies that you employ?

12. Could you describe the decision-making process regarding whether to patent the invention?

13. Could you describe how you recruit companies who might be interested in the invention?

14. How do you measure the potential commercial viability of a new technology?

15. How much time is spent in your office on renegotiations? Do you have a suggestion for reducing this?

16. What is the most common reason for termination of an agreement?

Interview questions for other university research administrators (e.g., Vice Provost for Research):

1. How do you define technology transfer? What are the outputs?

2. How has the process of technology transfer changed over time? Has the relative importance of specific outputs changed over time?

3. What data do you collect to measure technology transfer performance? Ideally, what would be the best data to collect?

4. What are the impediments to successful technology transfer?

5. How would you improve the process?

6. What is your university's overall strategy for technology transfer?

7. In recent years, has your institution's reward structure changed to promote technology transfer? Do you think it should?

Interview questions for managers and entrepreneurs:

1. How do you define technology transfer? What are the outputs?

2. How do you measure the success of technology transfer?
3. What are the impediments to successful technology transfer?
4. How would you improve the process?
5. How would you characterize your relationships with the TTO?
6. How would you characterize your relationships with university scientists?
7. What individuals do you network with at the university? What type of communication is involved in such networking?
8. How do you measure the potential commercial viability of a new technology?

Interview questions for academic scientists:

Please describe your personal experiences with technology transfer.

2. What are the impediments to successful technology transfer?
3. How would you improve the process?
4. How much of your time is spent with the business community? With TTO personnel?
5. How many industry scientists do you interact with? Are these your former graduate students? What is the nature of this interaction? What percentage of your time is devoted to this activity? Has your TTO facilitated these relationships?
6. How much does your university/college/department value technology transfer? Has this changed in recent years?
7. How would you characterize your relationships with the TTO?

References

T.J. Allen. *Managing the flow of technology: technology transfer and the dissemination of technological information within the R&D organization*. MIT Press, Cambridge, MA (1984)

D.G. Ancona, D.F. Caldwell. *Bridging the boundary: external activity and performance in organizational teams*. *Administrative Science Quarterly*, 37 (1992), pp. 634–666

R. Ashkenas, D. Ulrich, T. Jick, S. Kerr. *The boundaryless organization*. Jossey-Bass, San Francisco (1995)

- J. Bercovitz, M. Feldman, I. Feller, R. Burton. Organizational structure as a determinant of academic patenting and licensing behavior: an exploratory study of Duke, Johns Hopkins, and Pennsylvania State Universities. *Journal of Technology Transfer*, 26 (2001), pp. 21–135
- K. Butterfield, L. Trevino, G. Ball. Punishment from the manager's perspective: a grounded investigation and inductive model. *Academy of Management Journal*, 39 (1996), pp. 1479–1512
- K.M. Eisenhardt. Agency- and institutional-theory explanations: the case of retail sales compensation. *Academy of Management Journal*, 31 (1988), pp. 488–511
- M.P. Feldman, A.N. Link, D.S. Siegel. *The economics of science and technology*. Kluwer Academic Publishing, Norwell, MA (2002)
- L.R. Gomez-Mejia, D.B. Balkin. Determinants of faculty pay: an agency theory perspective. *Academy of Management Journal*, 35 (1992), pp. 921–955
- R. Jensen, M.C. Thursby. Proofs and prototypes for sale: the licensing of university inventions. *American Economic Review*, 91 (2001), pp. 240–259
- R. Katz, M. Tushman. A longitudinal study of the effects of boundary spanning supervision on turnover and promotion in research and development. *Academy of Management Journal*, 26 (1983), pp. 437–456
- J. Liebeskind, A. Oliver, L. Zucker, M. Brewer. Social networks, learning, and flexibility: sourcing scientific knowledge in new biotechnology firms. *Organization Science*, 7 (1996), pp. 428–443
- K.S. Louis, L.M. Jones, M.S. Anderson, D. Blumenthal, E.G. Campbell. Entrepreneurship, secrecy, and productivity: a comparison of clinical and non-clinical faculty. *Journal of Technology Transfer*, 26 (2001), pp. 233–245
- E. Marshall. Japan and the economics of invention. *Science* (1985, April 12), pp. 157–158
- M.B. Miles, A.M. Huberman. *Qualitative data analysis*. (2nd ed.) Sage Publications, Thousand Oaks, CA (1994)
- R.R. Nelson. Observations on the post-Bayh–Dole rise of patenting at American Universities. *Journal of Technology Transfer*, 26 (2001), pp. 13–19
- W.W. Powell. Neither market nor hierarchy: network forms of organization. *Research in Organizational Behavior*, 12 (1990), pp. 295–336
- J. Poyago-Theotoky, J. Beath, D. Siegel. Universities and fundamental research: policy implications of the growth of university–industry partnerships. *Oxford Review of Economic Policy*, 18 (2002), pp. 10–21

E. Press, J. Washburn. The kept university. *Atlantic Monthly*, 285 (3) (2000), pp. 39–54

Siegel, D., Waldman, D., & Link, A. (1999). Assessing the impact of organizational practices on the productivity of university technology transfer offices: an exploratory study. National Bureau of Economic Research Working Paper No. 7256, July and in press, *Research Policy*.

P. Stephan. Educational implications of university–industry technology transfer. *Journal of Technology Transfer*, 26 (2001), pp. 199–205

US General Accounting Office. *Technology transfer: administration of the Bayh–Dole Act by research universities*. Author, Washington, DC (1998)

L.G. Zucker, M.R. Darby. Star scientists and institutional transformation: patterns of invention and innovation in the formation of the biotechnology industry. *Proceedings of the National Academy of Sciences*, 93 (1996), pp. 709–716