Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies.

By: Donald S. Siegel, David A. Waldman and Albert N. Link

Siegel, D. S., Waldman, D. A., Atwater, L. E., & Link, A. N. (March 01, 2004). Toward a model of the effective transfer of scientific knowledge from academicians to practitioners: qualitative evidence from the commercialization of university technologies. *Journal of Engineering & Technology Management, 21(1-2):*115-142.

Abstract:

A new organizational entity has emerged at research universities: the technology transfer office (TTO). TTOs were established to facilitate commercial knowledge transfers from universities to practitioners or university/industry technology transfer (UITT). Despite the potential importance of UITT in fostering technological diffusion and as a source of revenue to the university, there has been little systematic analysis of the role of organizational practices in this process. Thus, we rely on an inductive, qualitative approach to identify the key organizational issues in promoting successful knowledge transfers. Based on 55 structured interviews of 98 UITT stakeholders associated with five US research universities, we conclude that there are numerous impediments to effectiveness in UITT: cultural and informational barriers among the three key stakeholder types (university administrators, academics, and firms/entrepreneurs), TTO staffing and compensation practices, and inadequate rewards for faculty involvement in UITT. Two somewhat surprising results are that many faculty members have decided to circumvent the formal UITT process and that involvement in UITT may actually increase the quantity and quality of basic research.

Keywords: university/industry technology transfer | technology transfer offices | boundary spanning | technology commercialization | technology management | knowledge transfer

Article:

1. Introduction

American universities have been criticized for being more adept at developing new technologies than moving them into private sector applications (General Accounting Office, 1998). In a similar vein, policymakers have often maintained that the long lag between the discovery of new

knowledge at the university and its use by firms could seriously impair the global competitiveness of American firms (Marshall, 1985). In 1980, Congress attempted to remove potential obstacles to university/industry technology transfer (UITT) by passing the Patent and Trademark Act, otherwise known as the Bayh-Dole Act. Bayh-Dole instituted a uniform patent policy, removed many restrictions on licensing, and allowed universities to own patents arising from federal research grants. 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 seeking to commercialize university-based technologies. In the aftermath of this legislation, many universities established technology transfer offices (TTOs) to manage and protect their intellectual property. The role of the TTO is to facilitate commercial knowledge transfers through the licensing to industry of inventions or other forms of intellectual property resulting from university research. Accordingly, the number of patents granted to US universities has increased from 300 in 1980 to 3661 in 1999, while licenses have increased almost 12-fold since 1991. Membership in the Association of University Technology Managers (AUTM), which represents licensing officers at universities and other research institutions, has increased from less than 100 in 1980 to over 2000 in 1998. Annual licensing revenue has risen from about US$ 160 million in 1991 to US$ 862 million in 1999, now constituting about 2.7% of university R&D expenditures. More importantly, major products in a wide variety of industries have been developed through UITT, such as internet search engines (e.g., Lycos), the Boyer-Cohen “gene-splicing” technique that launched the biotechnology industry, diagnostic tests for breast cancer and osteoporosis, music synthesizers, computer-aided design (CAD), and environmentally-friendly technologies (General Accounting Office, 1998).

Despite the potential importance of UITT as a source of revenue to the university and as an engine of economic growth, there has been little systematic analysis of organizational practices in the management of university intellectual property. An exception is a study of 62 university TTOs by Thursby et al. (2001). While the authors report that these offices appear to have common marketing procedures, they do not directly examine managerial and organizational practices. Further, given that the stakeholders in this process (i.e., university scientists, university administrators, and firms/entrepreneurs) have different motives and behaviors, and operate in different cultural environments, there is room for considerable disagreement and misunderstanding.

The primary goal of this study is to improve our understanding of UITT, based on an inductive analysis of qualitative evidence gathered from UITT stakeholders at academic institutions and firms. We believe that an inductive, qualitative approach is warranted for two reasons. First, our review of the management literature indicates that little has been written on how knowledge transfers between universities and industry actually occur or the obstacles that are encountered in facilitating these transfers. An exception is a recent paper by Argyres and Liebeskind (1996) that focuses on broad managerial policies. The authors contend that the university's "social–contractual" commitment to open science and its unique governance structure serve as barriers to the commercialization of biotechnology research. Furthermore, it is also important to note that university management of intellectual property itself is in an embryonic stage of development. Thus, there is much to be learned by sharing ideas and experiences, and identifying the most promising collaboration strategies for promoting successful UITT.

A second reason for adopting an inductive approach is that many of the issues associated with technology transfer are both ambiguous and highly contentious. For example, there are disputes regarding ownership rights to intellectual property, potential conflicts of interest for scientists who become involved with corporate sponsors or commercial endeavors, and pressures from influential donors, faculty, and external constituents. We suggest that it is important to identify the key structural and institutional barriers to UITT so that management theories can be developed to shed greater light on what can be done to extirpate them. If university technology managers and administrators can identify ways to manage their intellectual property more effectively, the end result will be a more rapid rate of technological diffusion and greater economic prosperity.

The remainder of this paper is organized as follows. In the next section, we outline and describe the process of UITT. Next, we identify the key UITT stakeholders and outline a set of research questions to guide our field research. Based on these qualitative findings, we outline a model that highlights the role of organizational and managerial practices in improving knowledge transfer between university scientists and practitioners. We also develop a set of propositions to guide additional empirical research.

2. Technology transfer in a university setting

In the management literature, technology transfer is usually considered within or across firms, such as the dissemination of information through transfers of employees from one division or country to another. For example, Allen (1984) focused specifically on the flow of technology transfer within a large R&D organization, or R&D subunit of a larger organization. Agmon and

Von Glinow (1991) examined the role of the multinational corporation in facilitating commercial knowledge transfers across countries.

In this paper, we focus instead on the UITT process, whereby technologies originate in universities and are ultimately used by industry. We contend that the key UITT stakeholders are: (1) university scientists, who discover new technologies; (2) university technology managers and administrators, who serve as a liason 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 these research projects, can also be viewed as a stakeholder.

Fig. 1 presents a schematic of the transfer of technology from a university to a firm or entrepreneur. We wish to stress that this general linear flow model of UITT reflects the conventional wisdom among academic administrators (see AUTM (2000)) regarding how technologies are transferred. It does not necessarily constitute an accurate representation of how they are actually transferred. Indeed, a key goal of our field research is to determine whether this model understates the complexity of this process.

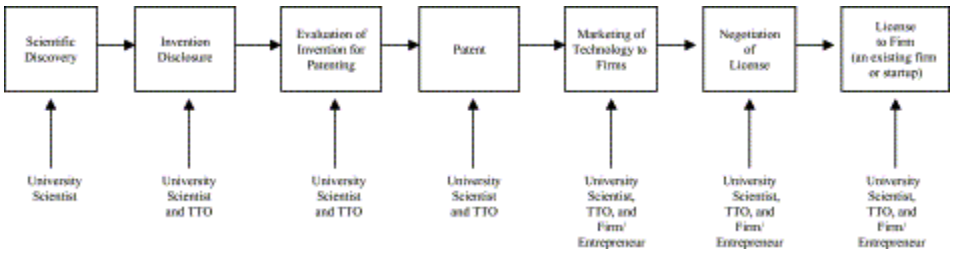

Fig. 1. How a technology is transferred from a university to a firm or entrepreneur (according to theory).

According to Fig. 1, the process is presumed to begin with a discovery by a university scientist in a laboratory, who is working on a federal research grant (e.g., a research project funded by the National Institutes of Health). As stipulated in the Bayh-Dole Act, the academic is then required by law to file an invention disclosure with the TTO. University officials must then decide whether they will attempt to patent the innovation, which is one mechanism to protect intellectual property. Interest in the technology by an industry partner often provides sufficient justification for filing a patent. In other cases, the TTO must make a judgement regarding commercialization potential prior to interest being expressed by industry. This is not a trivial decision, because universities have limited budgets for filing patents, which is quite expensive if global patent protection is sought. Universities may choose to apply for domestic patent protection, which safeguards the technology at a much lower cost.

Once the patent has been awarded, the TTO can presumably market the technology, sometimes with faculty input. That is, faculty members can help identify potential corporate licensees. The next stage of the model involves working with firms or entrepreneurs to negotiate a licensing agreement. This agreement could include such benefits to the university as royalties or an equity stake in a startup. In the 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 startups, faculty members may serve as technical advisors or on boards of directors, and may also have an equity stake in the startup.

Another perspective on UITT involves the consideration of the actions, motives, and organizational cultures of scientists, university administrators, and firm/entrepreneurs, which we present in Table 1. According to Merton (1957), a primary motive of university scientists is recognition within the scientific community, which emanates from publications in top-tier journals, presentations at prestigious conferences, and federal 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. As noted in Friedman and Silberman (2003), all universities have a "royalty distribution formula," which determines the fraction of a licensing royalty payment that is allocated to a faculty member (typically ranging from 25 to 50%).

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

Stakeholder	Actions	Primary motive(s)	Secondary motive(s)	Organizational culture
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

As noted in Siegel et al. (2003), the TTO works with the scientist and firm or entrepreneur to structure a deal. The primary motive of the TTO is to safeguard the university's intellectual property, but at the same time, market that intellectual property to private firms. Secondary motives may 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 actions and motives of firms and entrepreneurs are relatively straightforward. They seek to commercialize university-based technologies for financial gain. To do so, they desire exclusive rights to these technologies, in order to maintain control. They also express great anxiety about "time to market," since the benefits from innovation may depend on rapid development of a new product or new process.

Differences in the motives, actions, and organizational cultures of the three key stakeholders underscore the potential importance of organizational and managerial factors in UITT. A key goal of our field research is to improve our understanding of these differences, so that we can identify a set of organizational and managerial practices that may be relevant to overcoming barriers to UITT. Following Dougherty (1992), these different cultures could constitute distinct "thought worlds" with distinct languages and organizational routines that impede technology transfer. Before discussing our field research, which involved structured interviews of these three stakeholder groups, we attempt to identify a set of general research questions to guide our qualitative analysis. We are especially interested in formulating questions that highlight the role of university TTO managers, since they are charged with the responsibility of managing this process.

In this regard, boundary spanning (Katz and Tushman, 1983 and Tushman, 1977) may be a critical skill/behavior for TTO managers. Such behavior could include actions taken by managers to serve as a bridge between "customers" (entrepreneurs/firms) and "suppliers" (scientists) who operate in distinctly different environments. Roberts (1988) finds that such "bridging mechanisms" are important in UITT. For example, the TTO may scan the external environment for ideas and information about potential markets for new technologies. Such behavior would bring TTO managers into contact with entrepreneurs and intrapreneurs in the business domain. Without effective boundary spanning, the needs and interests of customers may not be adequately transmitted to suppliers, and the capabilities and interests of suppliers may not be adequately transmitted to customers. In sum, boundary spanning on the part of TTO managers could involve relationship or network building that helps to facilitate effective communication with both stakeholder groups and forges alliances between scientists and industry.

In many universities, the TTO director may have limited discretion and responsibility for technology transfer. That is, a vice-provost or vice-president for research will bear ultimate responsibility for these activities. Furthermore, a university president or provost may be responsible for establishing an organizational culture that fosters technology transfer. Recognizing the importance of technology transfer as a source of revenue and local economic development, a president or provost could establish UITT as an important organizational objective and devote a substantial amount of time and effort to monitoring performance in this area. Also, standards for promotion and tenure in science and engineering might reflect these objectives. In sum, an organizational culture that fosters technology transfer is also likely to be one that places a strong weight on developing good relationships with customers and suppliers, and a strong organizational emphasis on UITT.

Thus, it is clear that various organizational and managerial variables could be critical in explaining variation in UITT across universities. Furthermore, an inductive approach is warranted given that university management of intellectual property is a relatively new phenomenon, and the fact that there has been no systematic research of organizational/managerial practices in UITT. In addition, although much of the existing literature stresses commercialization of university-generated technology as the predominant outcome, we also sought to ascertain how stakeholders themselves define the outputs of UITT.

In sum, the extant literature suggests the following research questions:

Research question #1:	How do stakeholders of UITT define the outputs of the process?
Research question #2:	How does the formation of relationships, networks, or boundary spanning behavior affect UITT?
Research question #3:	What are the organizational/managerial barriers to UITT?
Research question #4:	How can organizational factors and managerial behaviors be improved to help facilitate UITT?

3. Method

Stakeholder interviews constituted the primary unit of analysis for our research. As such, our data are based on structured, in-person interviews of key constituents including TTO directors and university administrators, managers/entrepreneurs, and academic scientists associated with: (1) Duke University; (2) the University of North Carolina at Chapel Hill; (3) North Carolina State; (4) Arizona State University; and (5) the University of Arizona. We acknowledge that ours is a convenience sample. We did not examine elite institutions in regions that are considered hotbeds of technology transfer activity, such as Cambridge/Boston (MIT and Harvard) or the San Francisco Bay area (Stanford and UC-Berkeley), which have been the focus of much of academic literature (e.g., Mowery et al., 2001). It may actually be inappropriate to make generalizations regarding UITT management practices from the experiences of such non-representative institutions. That is, such schools may have extremely favorable conditions for UITT (e.g., a strong scientific and engineering base and readily available venture capital) that enable them to generate high levels of UITT output (i.e., patents, licenses, and startups) without any assistance from the TTO or university administrators. Thus, their "success" may not be due to their ability to manage the UITT process effectively, but rather to factors that are beyond the control of university administrators.

In contrast, we have chosen to analyze UITT at more representative Research One universities for two reasons. First, despite the common perception that UITT occurs almost exclusively at top-tier universities in major metropolitan areas (e.g., MIT and Stanford), the bulk of licensing activity actually takes place at modal institutions. According to AUTM (2000), six of the top 10 universities (over the period 1991–1996) in generating licensing agreements were land grant institutions (Michigan State, Wisconsin, Florida, Iowa State, Minnesota, and Purdue). Two of the five universities in our field study (the University of Arizona and North Carolina State) are land grant institutions.

A second reason for examining modal universities is that such schools are more likely to deal with a larger number of companies, especially smaller firms located near the university. Thus, they have numerous relationships with local firms, making it easier for us to draw a broader group of industry respondents for our qualitative study. Finally, we note that our sample does include institutions that have been successful in UITT, if one adopts a broader view regarding success, as reflected in the impact of the university on high technology activity the local region. Three of the schools we visited (the University of North Carolina at Chapel Hill, North Carolina State, and Duke University) are located near one of the world's most successful science parks: Research Triangle Park. We also interviewed many entrepreneurs and representatives of firms

whose firms are located at or around the park. As noted in Link and Scott (2003), policymakers and university administrators alike are interested in emulating the success of the park.

The top panel of Table 2 presents some information on the characteristics of the five universities that we visited. These include private and public universities, land grant institutions, and universities with and without a medical school. There is also considerable variation with respect to the size of the TTO (number of professional, full-time equivalent staff members) and the extent of licensing activity, as measured by the number of licensing agreements or licensing revenue. Note also that each school established a TTO soon after the enactment of Bayh-Dole (1980). In the bottom panel of Table 2, we compare mean values of the same variables for the five institutions we visited and all research one universities (derived from the full AUTM sample, excluding teaching hospitals and Canadian institutions). These statistics indicate that the schools we visited are quite similar to the average AUTM respondent along each of these dimensions (with the exception of licensing revenue), which lends further credence to our assertion that the universities in our study are representative. Thus, although ours is admittedly a convenience sample, it does have certain advantages.

Table 2. Characteristics of the five case universities

	Duke University	University of North Carolina at Chapel Hill	North Carolina State	Arizona State University	University of Arizona
Organizational status	Private	Public	Public	Public	Public
Medical School	Yes	Yes	No	No	Yes
Land Grant Institution	No	No	Yes	No	Yes
Year in which TTO was established	1984	1985	1982	1985	1988
Number of professional FTE in TTO	14.2	11.5	11.1	2.9	8.5
Average Annual Licensing Agreements (1991–1996)	28.1	19.0	26.1	3.4	12.0
Average Annual Licensing Revenue (1991–1996) (US$ 000)	1213.2	773.3	1535.7	382.7	177.0

Variable name	Description	Five universities in our field study	113 research one universities		
Comparison of mean values of variables for field sample and 113 research one universities					
License 1	Average Annual Licensing Agreements (1991–1996)	17.7	14.3		
License 2	Average Annual Licensing Revenue (US$ 000) (1991–1996)	816.4	1803.7		
Staff	Average annual TTO employees	9.6	9.1		
Age	Numbers of years since TTO was established (as of 1996)	11.1	12.5		

Source: Association of University Technology Managers (1997).

At each university, we interviewed the TTO director, at least one administrator who oversees the TTO, typically a vice-provost, vice-president, or vice-chancellor for research, and academic scientists who have transferred technologies. Although a team of researchers is typically involved in a given transfer, most of the scientists with whom we met were leading such a team. Furthermore, each scientist had been involved in negotiating a licensing agreement or forming a startup. Thus, we believe that our inability to interview all members of each scientific team does not detract from our data or analyses. Within the surrounding region of the university, we also met with industry-based individuals who had been associated with UITT activities of a respective university. These included founders of startup companies, directors of business development, intellectual property managers, and other research managers at large companies, as well as managers of patent management firms and non-profit 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 and constitute a neutral third party. 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 faculty members (i.e., scientists) and managers/entrepreneurs with a wide variety of perspectives on UITT and many relationships with TTOs.

In sum, a stratified approach was used to select interviewees, so that they would be drawn from each of the three constituent groups. We conducted 55 interviews: 20 managers/entrepreneurs, 15 administrators (5 TTO directors and 10 other administrators), and 20 university scientists. Although there were only 55 distinct, face-to-face meetings, we actually spoke with 98 individuals, since multiple respondents were present at some meetings. However, as noted earlier, the interview itself (N=55) served as the unit of analysis.

Our interviewees included managers/entrepreneurs of large and small firms, as well as faculty members in a number of academic disciplines (physics, biology, chemistry, medicine, pharmacology, and engineering) at different ranks. By sampling across different scientific disciplines and faculty ranks, we provide a broader perspective on UITT issues, as compared to prior research. For instance, Lee (2000) reports that full professors may be more likely than assistant and associate professors to disclose inventions and patent. We also did not want to focus our analysis exclusively on life science faculty, as other researchers have done in previous studies (e.g., Blumenthal et al., 1996).

The interview data consist of open-ended responses to questions posed by our research team. These queries were designed to elicit information relevant to the four research questions outlined in the previous section. Many of these questions were the same across stakeholder groups. For instance, all interviewees were asked to define technology transfer and to identify its outputs, barriers/impediments to successful technology transfer, and suggested improvements to the UITT. Other questions were tailored to a specific group, given the specialized knowledge of respondents in that stakeholder category. For example, TTO directors and other university administrators were asked to identify and comment on the nature of their university's overall strategy for technology transfer and their negotiation strategies with firms. On the other hand, academics alone were asked to comment on their interactions with industry scientists and their opinion of the extent to which their university, college, or department values technology transfer. Given that Fusfeld (1995) has found that students are an important mechanism for UITT, it is also useful that we asked academics to comment on their relationships with graduate students and post-doctoral fellows. Managers and entrepreneurs were asked to discuss how they measure the potential commercial viability of a new technology. In sum, a structured interview approach

was used with the same questions being asked either across or within respondent types, as deemed appropriate.

We also took several steps to increase the accuracy and reliability of the data. These include neutral probing of answers, a pledge of confidentiality, and prior knowledge of the purpose of our study. As examples, Fleisher and Nickel (1995) and Waldman et al. (1998) used similar procedures. On average, the interviews lasted approximately 1 h and were tape-recorded and transcribed by a typist. This third-party transcription ensured a complete and unbiased recording of interview data (Eisenhardt, 1989). Following Bryman (1989), interviewees were promised a study report of aggregated findings, a procedure that often serves to motivate involvement.

As outlined in Miles and Huberman (1994), we employed three major stages of qualitative data analysis of interviews: data reduction, data display, and conclusion drawing/verification. Data reduction involves the selection, simplification, and transformation of raw data into an analyzable form. We began with an initial list of general categories for content analysis purposes. These categories were largely based on the initial research questions.

Miles and Huberman (1994) note that it is common for coding categories to be adjusted because of a poor fit or the need to add and combine classifications. Indeed, an initial review of 15 transcripts indicated that comments relevant to one of our initial categories (aspects of the TTO) should be combined with other categories. Subsequently, for each interview, all comments were independently categorized by two members of the research team into four areas, which roughly correspond to our four research questions: (1) the nature of UITT outputs; (2) UITT networks/relationships; (3) organizational/managerial 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 et al. (1996), who identified unique "thought units" pertinent to their subject of interest (employee discipline).

Following identification of relevant comments in each topic area, each researcher examined five interview transcripts to generate a list of more specific themes within the above categories. The research team then met and discussed the categories that emerged. There was a great deal of similarity in the lists of categories that emerged from the separate samples of comments.

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. That is, we generated tables with cells that indicate the percentage of respondents (for each stakeholder category) that mentioned a particular theme that is relevant to the four research questions. Unfortunately, we do not have a measure of the intensity of feeling about a particular issue or theme. Thus, something is considered to be “important” if respondents were inclined to discuss it during our interviews. Although this method has its drawback, such an approach is commonly employed in such an inductive study, such as ours.Table 3, Table 4, Table 5 and Table 6 present the percentage of respondents who identified themes relevant to outputs, relationship/networks, barriers, or suggested improvements, by stakeholder group. This illustrates how qualitative research can be quantified (Bryman, 1989). Proportion tests of differences (Z-tests) were used to compare whether the percentage of respondents endorsing a theme in a given group differed from the percentage of respondents endorsing a theme in another group. For example, Z12 compares managers/entrepreneurs (Group 1) with TTO directors/administrators (Group 2).

Table 3. Outputs of university/industry technology transfer (UITT) as identified by interviewees

Outputs	Type of interviewee			Z_{12}	Z_{13}	Z_{23}
	(1) Managers/entrepreneurs	(2) TTO directors/administrators	(3) University scientists			
Licenses	75.0	86.7	25.0	−1.37	2.14**	3.24*
Royalties	30.0	66.7	15.0	−1.74	0.91	2.61*
Patents	10.0	46.7	20.0	−2.91*	−0.84	2.23**
Sponsored research agreements	5.0	46.7	0.0	−2.72*	0.44	3.33*
Startup companies	5.0	33.3	10.0	−2.07**	−0.56	1.64
Invention disclosures	0.5	33.3	5.0	−2.81*	−0.99	2.28*
Students	25.0	26.7	15.0	−0.22	0.88	1.22
Informal transfer of know-how	70.0	20.0	20.0	2.69*	3.31*	0.03

Product development	40.0	6.7	35.0	2.08**	0.12	−2.01**
Economic development	35.0	20.0	0.0	0.52	2.98*	2.03**
Number of interviews	20	15	20			

Note: The values presented in columns (1)‑(3) are the percentages of respondents who identified a particular item as an output of UITT. The values displayed in the last three columns are *Z* statistics for differences in proportions between each class of interviewee.

* $P<0.01$.

** $P<0.05$.

Table 4. Aspects of relationships/networks in university/industry technology transfer (UITT) as identified by interviewees

Relationships/networks	Type of interviewee			Z_{12}	Z_{13}	Z_{23}
	(1) Managers/entrepreneurs	(2) TTO directors/administrators	(3) University scientists			
Personal relationships	75.0	66.7	80.0	0.68	−0.42	−1.63
TTO as a facilitator of relationships between scientists and firms	26.3	75.0	40.0	−2.65*	−0.91	1.92
Knowledge transfer from industry to faculty members	25.0	20.0	65.0	0.35	−2.46*	−297*
Conference/expos/Town Hall meetings on TT issues	35.0	80.0	15.0	−2.34**	1.59	3.56*
Contractual relationships	15.0	6.7	0.0	0.84	1.80	1.02
Number of interviews	20	15	20			

Note: The values presented in columns (1)‑(3) are the percentages of respondents who identified a particular item as an aspect of relationships/networks in UITT. The values displayed in the last three columns are *Z* statistics for differences in proportions between each class of interviewee.

* $P<0.01$.

** $P<0.05$.

Table 5. Barriers to university/industry technology transfer (UITT) as identified by interviewees in our field study

Barriers	Type of interviewee			Z_{12}	Z_{13}	Z_{23}
	(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	−0.25	1.19	1.30
Insufficient rewards for university researchers	31.6	60.0	70.0	−1.29	−2.46*	−1.03
Bureaucracy and inflexibility of university administrators	80.0	6.6	70.0	3.96*	0.74	−3.51*
Insufficient resources devoted to technology transfer by universities	31.6	53.3	20.0	−0.95	0.93	2.05**
Poor marketing/technical/negotiation skills of TTOs	55.0	13.3	25.0	2.07**	1.91	−0.71
University too aggressive in exercising intellectual property rights	80.0	13.3	25.0	3.30*	2.94*	−0.91
Faculty members/administrators Have unrealistic expectations regarding the value of their technologies	25.0	40.0	10.0	−0.94	1.13	1.90
“Public domain” mentality of universities	40.0	8.3	5.0	1.86	2.60*	0.38
Number of interviews	20	15	20			

Note: The values presented in columns (1)‑(3) are the percentages of respondents who identified a particular item as a barrier to UITT. The values displayed in the last three columns are *Z* statistics for differences in proportions between each class of interviewee.

* $P<0.01$.

** $P<0.05$.

Table 6. Suggested improvements to the university/industry technology transfer (UITT) process, as identified by interviewees

Improvements	Type of interviewee			Z_{12}	Z_{13}	Z_{23}
	(1) Managers/entrepreneurs	(2) TTO directors/administrators	(3) University scientists			
Universities and industry should devote more effort to developing better mutual understanding	80.0	93.3	75.0	−0.96	0.33	1.28
Modify reward systems to reward technology transfer activities	85.0	80.0	80.0	0.35	0.36	−0.00
Universities need to provide more education to overcome informational and cultural barriers	85.0	86.7	60.0	−0.09	1.70	1.74
Universities should devote additional resources to technology transfer	45.0	46.7	60.0	0.11	−1.00	−1.25
Universities should be less aggressive in exercising intellectual property rights	55.0	10.0	15.0	2.52*	2.62*	−0.36
Increase networking between scientists and practitioners	35.0	26.7	40.0	0.65	−0.34	−1.09
Universities need greater marketing Expertise in the TTO	50.0	20.0	25.0	1.76	1.54	−0.37
Number of interviews	20	15	20			

Note: The values presented in columns (1)–(3) are the percentages of respondents who identified a particular item as a suggested improvement to UITT. The values displayed in the last three columns are *Z* statistics for differences in proportions between each class of interviewee.

* $P<0.01$.

4. Results

4.1. Stakeholder perceptions of UITT outputs

Table 3 presents outputs identified by each stakeholder group. The outputs most frequently mentioned by TTO directors and university administrators were licenses (86.7%) and royalties (66.7%). This is not surprising since these activities generate revenue for the university. To a somewhat lesser extent they also identified patents (46.7%), and sponsored research agreement (46.7%) as outputs. Although managers and entrepreneurs identified licenses as an output, they also mentioned broader notions of output, such as new products, profit, and economic development. Informal transfer of know-how (70.0%) was the second most frequently mentioned output by managers/entrepreneurs. Z statistics presented in Table 3 (2.69 and 3.31) indicate that informal knowledge transfer was viewed to be significantly more important by managers than other stakeholders. 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.

University scientists most frequently identified product development and licenses as outputs, although they are somewhat reluctant to think of the process in terms of generating output. One interpretation of this finding is that they could not reach a consensus on outputs because they are too focused on their own role in this process and fail to see the big picture. Another possible explanation of this result is that they view themselves as being removed from the process of commercialization.

Recall that in our framework, TTO managers serve as a bridge between university scientists and firms/entrepreneurs. The general pattern of results presented in Table 3, especially the numerous significant values of Z statistics testing differences between university administrators and firms/entrepreneurs (Z12) and scientists (Z23), reveal striking differences in perceptions regarding the outputs of UITT. These perceptual differences provide some insight into the

organizational conflict that may arise when firms and universities negotiate a licensing agreement. For instance, firms appear to place a much stronger weight on factors that do not necessarily generate additional revenue for the university (e.g., informal transfer of know-how and product development), while university administrators appear to be focused on those dimensions that generate additional research income.

A final result is that all three groups, including administrators, do not seem to view entrepreneurial startups as a critical output of UITT, despite recent efforts to promote academic startups at universities (Feldman et al., 2001). An analysis of the interview transcripts reveals that although one-third of university administrators (see Table 3) mentioned new firm creation as an output, almost all of their discussion focused on other dimensions of UITT, mainly licensing, patenting, and sponsored research. Academics were even more silent on the notion of startups as an output.

These different perceptions about the outputs of UITT can be a source of tension. At one institution, the vice-provost for research boasted about his university's efforts to enhance new firm creation. An academic at the same university made his antipathy toward this initiative quite apparent, by stating the following:

> I know that our university wants to see more academic startups but I think that is the wrong way to go. I do not encourage my students or colleagues to go down that road. We need to stop pretending that academics can be entrepreneurs, or at least good ones.

Such findings suggest that university officials who wish to promote this mode of technology transfer need to devote more time and effort to ensuring that such goals permeate their institutions.

4.2. Relationships/networks

Table 4 contains aspects of relationships/networks that stakeholder groups endorsed as important in UITT. TTO directors and administrators mention the TTO's facilitator role more frequently than other stakeholders (75.0% versus 40.0 and 26.3%). Some managers and scientists described the TTO as an obstacle rather than a facilitator. One manager commented:

It's the technology transfer office that is giving us trouble, so we are trying to go around them.

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.

All three stakeholder groups (75, 67, and 80% of the firms, administrators, and academics, respectively) stressed the importance of personal relationships in UITT. One scientist commented:

> I find it refreshing that companies realize that teaming with academic entities, academic professors, and laboratories allows them to move their entire industry forward in the point of view of technology development.

University administrators (80%) acknowledged the importance of conferences to display new technology and meetings on UITT issues. A TTO director stated:

> Last year we had a Town Hall meeting, where we brought together all the parties to hash out all the thorny intellectual property issues. There was a lot of tension at first, but I think it was really useful for them to hear our side of the story and understand some of our constraints.

Managers/entrepreneurs also mentioned these conferences, but to a much lesser extent (35%). 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.

One interesting finding that somewhat contradicts the conventional wisdom of Fig. 1 is that knowledge transfer appears to work in both directions. Sixty-five percent of the scientists we interviewed explicitly mentioned this issue. Some even noted that interacting with firms enables them to conduct “better” basic research. 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.

Another academic stated that:

> My sponsored research projects allow me to use the company's equipment and other resources (we presume he meant industry scientists) to do research that I can't possibly do with the stuff we have here at my school. As a result, I think some of my best scientific work has been done through what you guys call technology transfer.

These results are somewhat surprising because the conventional wisdom is that there is a tradeoff between involvement in UITT and scholarly productivity. Our interview evidence is consistent with the findings of Zucker and Darby (1996). They reported that "star" scientists in biotechnology who become involved in UITT are actually more productive in a scholarly sense, while they are also engaged in helping firms commercialize technologies. In a similar vein, Louis et al. (2001) find that academic entrepreneurs tend to have higher scholarly productivity than non-entrepreneurial academics.

It is also interesting to note that for all groups, but especially for scientists, personal relationships involving scientists and managers/entrepreneurs were substantially more important (80%) than contractual relationships (0%). 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].

4.3. Barriers

We also solicited information from stakeholder on barriers to effective UITT. As shown in Table 5, all three groups identified a lack of understanding regarding university/corporate/scientific norms as a barrier to effective UITT (90.0, 93.3, and 75.0%). It appears as though scientists and

administrators do not understand or appreciate industry culture/constraints, and industry does not understand or appreciate university culture/constraints. Representative comments were:

> 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.

> University faculty members have a lack of understanding of what companies are trying to get at. Their attitude is just give us money and we'll solve your problem.

One administrator had a similar view. He 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.

Others viewed the issue as another group's problem. That is, respondents from firms thought that universities were out of touch with the private sector, while scientists thought that firms lacked an appreciation of academic culture. For example, an entrepreneur commented:

> I think TTOs in general don't understand what additional work, money and investment has to be put into something that is coming out of a basic laboratory in order to commercialize it.

An administrator discussing the views of the business community stated:

> 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.

Eighty percent of the managers/entrepreneurs perceive that universities are too aggressive in exercising intellectual property rights, resulting in a hard line on negotiations and excess concern

on the part of university administrators that they will not realize sufficient revenue. One former TTO director, now in industry, stated:

> 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’.

Managers (80.0%) and scientists (70%) frequently cited bureaucracy and inflexibility as barriers to UITT. We alluded to this earlier in the paper when we discussed the facilitating role of the TTO. Essentially, managers and scientists 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 they make you go through a whole bunch of hoops.

University administrators (60.0%) and scientists (70.0%) cited insufficient rewards for university researchers as a barrier to effective UITT, especially non-pecuniary factors. These groups noted that universities rarely reward academics involved in UITT, since most promotion and tenure decisions continue to be based almost exclusively on publications and federal research grants.

Finally, firms and entrepreneurs (55.0%) were inclined to point out that the marketing, technical, and negotiation skills of the TTO staff could be substantially improved. Comments from firms/entrepreneurs included:

> What it takes to be a successful technology transfer officer is being a deal maker, 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 technology transfer office, 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, our evidence suggests that TTOs are often either too narrowly focused on a small set of technical areas, or too focused on the legal aspects of licensing. It appears that the marketing aspect of the TTO is often given short shrift.

4.4. Improvements

Table 6 presents interview findings regarding suggested improvements in UITT. Not surprisingly, many suggestions involve addressing the impediments displayed in Table 5. Many of these comments were very rich and vivid, given the strong feelings respondents have regarding UITT issues. The consensus that emerged across stakeholder groups is quite striking. Note that almost all of the Z statistics are insignificant. However, in line with the above findings, managers and entrepreneurs suggested that universities be less aggressive in exercising their intellectual property rights. This could reflect the somewhat self-serving nature of our responses (since firms and entrepreneurs would directly benefit if universities were less aggressive) or instead, it may be indicative of a more general trend of over-zealousness of the part universities, in terms of commercialization activities (Press and Washburn, 2000).

Once again, we found strong evidence of the importance of cultural differences between stakeholder groups. Suggested improvements include increasing interaction and mutual understanding between universities and firms (80.0, 93.3, and 75.0%). 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?

This executive also thought that scientists should be made aware of the true costs of commercializing an invention and that many excellent technologies are commercial failures.

The need for greater marketing expertise among TTO staff was mentioned by half of 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. An administrator suggested:

> Someone should be there [in the TTO] who completely understands how to market the produce. Mostly the officers are patent attorneys or negotiating attorneys … no one from marketing.

Many respondents asserted that technology transfer activities should have a greater weight in promotion and tenure (P&T) 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.

Some scientists also discussed the importance of financial rewards. Not surprisingly, they wished to see a shift (in their favor) in the 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. In the schools we visited, there was considerable variation in the percentage of royalties allocated to faculty members (ranging from 30 to 70%). One department chair noted:

> At my former university, faculty members received 60% of the money from a license, while here it is 30%. This disparity has not been helpful, in terms of our ability to recruit and retain faculty members who are active in this area.

Some respondents were also troubled by the lack of resources devoted to technology transfer at the university. One company executive summed it up this way:

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

In the discussion below, we summarize the key findings of our qualitative analysis. Based on these results, we present a modified version of the model of UITT shown in Fig. 1. We use the modified version to formulate a set of propositions for future empirical analyses.

5. Discussion

5.1. General findings

Our evidence suggests that TTO directors and other university administrators stress dimensions of UITT that typically arise from formal agreements with companies and which generate revenue for their institutions, especially licensing. These findings are consistent with those reported in Thursby et al. (2001), who conducted a survey of university TTOs and found that directors of these offices typically perceive licensing to be the most important output of UITT. It appears that this emphasis on the contractual and pecuniary aspects of UITT appears to have brought universities into conflict with entrepreneurs and technology managers at firms, who are much more focused on informal modes of technology transfer. That is, companies seem to value interaction with the university (and its scientists) for its ability to enhance their "absorptive capacity," i.e., the ability to learn from external sources (see Cohen and Levinthal, 1990). On the other hand, university scientists were somewhat non-committal, in terms of identifying specific UITT outputs. Consistent with views expressed by managers and entrepreneurs, they appear to downplay the importance of patents, startup companies, and invention disclosures. However, they concur with their private sector counterparts regarding the significance of product development. The bottom line is that each group has vastly different perceptions of the nature of UITT outputs, which reflect their specific goals. Such contrary objectives can easily lead to misunderstandings or differing priorities.

Thus, it is perhaps not surprising that a key finding of our research is that cultural barriers are pervasive in UITT. It is clear that UITT stakeholders operate under different organizational environments and cultures, i.e., they have different norms, standards, or values. Nelson (2001)

noted how universities and firms differ in their perspectives on the role of knowledge. In general, firms do not share academic values regarding knowledge: publishing results and knowledge as a public good. Instead, technology is kept proprietary and used for strategic advantage in the pursuit of profits. The role of the TTO director as a boundary spanner may be critical in bridging these cultural gaps.

Another general finding is that personal relationships may be more important than contractual relationships in UITT. The need to increase networking between scientists and practitioners was also explicitly mentioned as a suggested improvement by about a third of all respondents. Taken together, these results imply that social networks may be somewhat critical in UITT. These networks include academic and industry scientists, and perhaps, university administrators and TTO directors. As defined by Liebeskind et al. (1996), social networks, like markets, involve exchanges between legally distinct entities. However, unlike markets, social networks support these exchanges without using competitive pricing or legal contracting. Instead, they rely on shared norms among the exchange partners. As such, these networks are able to generate what has been termed “social capital” (Coleman, 1988). The currency of exchange is information. Powell (1990) argued that social networks are the most efficient organizational arrangement for sourcing information because information is difficult to price in the marketplace, and it is difficult to communicate through a hierarchical structure.

Moreover, in high technology industries, organizations must devise arrangements that enable them to source a critical input—patentable/licensable scientific knowledge—in a highly efficient manner. Efficiency here refers to quick development and availability of scientific knowledge with relatively low sunk costs, e.g., internal R&D costs. Liebeskind et al. (1996) provided evidence of how social networks can increase organizational learning and flexibility in biotechnology.

We also find widespread belief that there are insufficient rewards for faculty involvement in UITT, especially for untenured faculty members who continue to be rewarded almost exclusively on the basis of publications and grants. This reward structure may be inconsistent with an organizational objective of promoting UITT, which is often featured prominently in university mission statements and newsletters. It may also be important to consider pecuniary rewards, such as the university’s royalty and equity distribution formula. Adjusting this formula in favor of the scientists could elicit more faculty involvement in UITT.

Staffing practices within the TTO are also a matter of concern. Recall that a TTO licensing officer is responsible for coordinating the activities that result in the consummation of a deal between the university (and its scientists) and a firm. Unfortunately, some firms and scientists expressed dissatisfaction with the marketing and negotiation skills of TTO personnel. Firms and scientists also frequently pointed to university bureaucracy and inflexibility as barriers to effective UITT. On a related point, firms also noted that universities are often too aggressive in exercising their intellectual property rights. While some of these firm perceptions may be due to a lack of understanding of university culture, they have the unfortunate effect of impeding the process of commercialization. Finally, there was also a widespread belief that universities are not devoting sufficient resources to technology transfer.

In sum, we find dissatisfaction with the UITT process along several dimensions. Our qualitative evidence also revealed that many scientists and firms are frustrated with the conventional UITT process, as managed by the TTO. This has led some scientists and practitioners to circumvent the TTO and engage in more informal types of UITT, such as consulting.

5.2. Reformulation of the UITT model

Based on our field research, we can reformulate our model of the UITT process. The revised model and associated propositions are shown in Fig. 2. Fig. 2 indicates that university reward systems affect faculty involvement in the patenting process. As noted earlier, the rewards for patenting in promotion and tenure are typically quite low. In fact, many senior faculty members look askance at junior faculty members who become involved in technology transfer. They allege that such activity is time taken away from fundamental research. This leads to our first proposition:

Proposition 1

. Universities that provide greater rewards for faculty involvement in technology transfer will generate more patents and licenses.

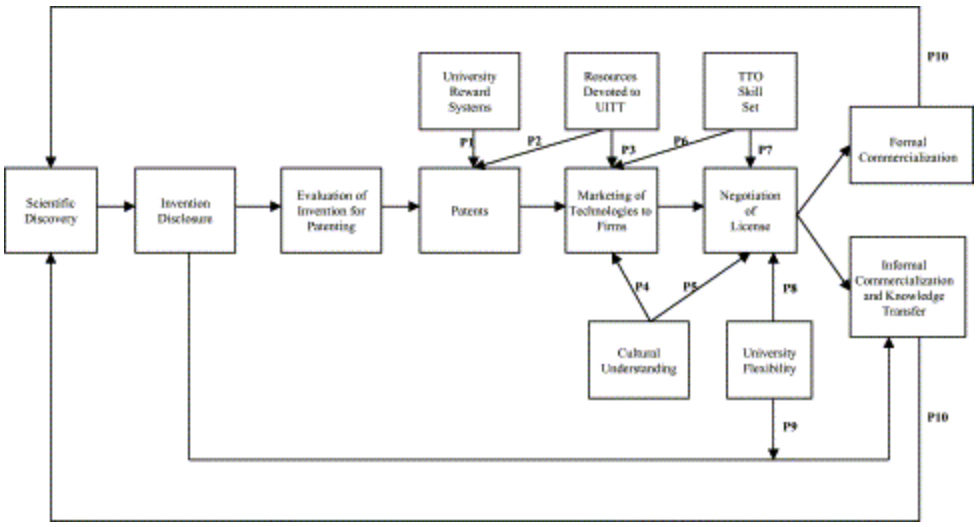

Fig. 2. Organizational and managerial issues in the university/industry technology transfer process.

Insufficient university resources was also cited as an impediment to UITT. As shown on Fig. 2, this affects the level of patenting, as well as the marketing of technologies to firms, because universities have a fixed budget to spend on patents. 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, as opposed to domestic patent protection, which is substantially cheaper. Similarly, a large TTO staff is often required to market university-based technologies effectively, especially when the reputation of the university is not sufficient 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. Some of the TTOs we visited are clearly understaffed, which implies that they have little time to devote to marketing. Thus, we have Proposition 2 and Proposition 3:

Proposition 2

. Universities that allocate more resources to the TTO will generate more patents and licenses.

Proposition 3

. Universities that allocate more resources to the TTO will devote more effort to marketing technologies to firms.

Another key finding is the pervasiveness of cultural misunderstanding, where culture is defined as a combination of assumptions, values, norms, and beliefs commonly shared by members of a social group that tends to shape the perceptions and behaviors of members of that group (Adler, 2002). Our analysis of this issue is complicated by the fact that, within universities, there are sub-cultures that weaken the extent to which values are indeed shared. Specifically, university scientists reflect one sub-culture, while university administrators reflect another. Managers and entrepreneurs need to understand that they are actually dealing with these two sub-cultures, which reflect conflicting goals, values, and beliefs. Recall that such cultural differences were vividly portrayed in Table 3, with respect to different perceptions regarding UITT outputs.

This misunderstanding of university culture (on the part of firms) can also diminish a TTO's ability to market its technologies. More importantly, it could significantly impede the process of negotiating a licensing agreement. Firms repeatedly expressed their frustration at the university's lack of a "deal-making" mentality. The university's risk aversion is especially frustrating for startup companies and other firms that need to respond quickly to changes in the competitive environment. This leads us to Proposition 4 and Proposition 5:

Proposition 4

. Cultural misunderstanding reduces the effectiveness of the university's efforts to market university-based technologies to firms.

Proposition 5

. Cultural misunderstanding impedes the negotiation of licensing agreements.

Many firms pointed to deficiencies in TTO marketing and negotiation skills. In theory, TTO personnel should be effective facilitators of UITT, i.e., they should engage in boundary spanning and bridging activities. Unfortunately, many TTOs are not actively recruiting licensing officers who possess such skills. Respondents who had relationships with numerous TTOs noted that those managed by directors with substantial business experience had a much firmer grasp on how to assess the market potential of a given technology and create linkages with firms. They also had a better understanding of the complexity of negotiations and how to remain flexible enough to consummate transactions. These observations lead to Proposition 6 and Proposition 7:

Proposition 6

. TTOs managed by individuals with marketing experience and skills will expend greater effort in establishing partnerships with firms.

Proposition 7

. TTOs that are managed by individuals with negotiation experience and know-how will be more successful at consummating technology transfer deals with firms.

With virtual unanimity, scientists and firms asserted that universities are too bureaucratic and inflexible in dealing with UITT issues. In defense of universities, especially public institutions, 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 constitute a public relations nightmare for universities, especially when they are lobbying for more funds in the state legislature. Thus, many schools have adopted a conservative negotiation stance, preferring to maximize royalties, even if this significantly reduces the probability of consummating the deal. A related point is that a university may sometimes refuse to accept an equity stake in a startup firm, in lieu of up-front royalty income. This yields Proposition 8:

Proposition 8

. A high degree of university inflexibility will result in fewer technology transfer agreements with firms/entrepreneurs.

Not surprisingly, this behavior frustrates many firms and scientists. As noted earlier, university inflexibility has led many firms and scientists to completely avoid working with the TTO. That is, when an invention is publicly disclosed, 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. In sum, as shown in Fig. 2, we expect that university inflexibility has a moderating effect, so that when inflexibility is high, university scientists will attempt to circumvent more formal UITT processes. These arguments lead to Proposition 9:

Proposition 9

. When university inflexibility is high, university scientists will circumvent formal UITT processes and rely on informal commercialization and knowledge transfer.

The conventional wisdom regarding UITT is that knowledge transfer works in one direction, i.e., from university scientists to firms. Several scientists we interviewed emphatically stated that knowledge transfer works in both directions. That is, as shown in the feedback loops in Fig. 2, formal and informal commercialization may actually lead to more scientific discoveries. For example, interacting with industry scientists may enable academic scientists to refine their experiments or spark ideas for new types of experiments. Furthermore, involvement in formal or informal commercialization often helps academics purchase additional laboratory equipment and graduate student assistance. The licensing agreement may also involve a commitment on the part of the firm to sponsor another research project at the university. One implication of the possibility that knowledge transfer flows in both directions is that the alleged tradeoff between basic and applied research may not be as severe as commonly perceived. Thus, we have our final proposition:

Proposition 10

. Universities that become involved in formal and informal UITT will experience an increase in basic research activity.

6. Conclusions

The purpose of this paper is to shed greater light on a salient trend: commercial transfers of knowledge from universities to firms, or university/industry technology transfer. Our inductive analysis of UITT was based on qualitative evidence collected from 55 structured interviews of three types of UITT stakeholders: firms/entrepreneurs, TTO directors and university administrators, and university scientists. Our interviews highlighted the importance of organizational and managerial behaviors and skills in facilitating effective UITT. This is also illustrated in our revised model of the UITT process, which takes such factors into account.

University management of intellectual property through a technology transfer office is a relatively new phenomenon. The managerial implications of our results are relatively straightforward. Administrators who wish to foster commercialization need to be mindful of the following organizational and managerial factors: (1) reward systems for UITT; (2) staffing practices in the TTO; (3) designing flexible university policies on technology transfer; (4) devoting additional resources to UITT, if that is consistent with the university's mission; and (5) working to eliminate cultural and informational barriers that impede the UITT process.

It would be useful to test the propositions we have outlined in our model. A first step would be to conduct a comprehensive survey of scientists, TTOs, and firms, in order to measure the variables in our model. These measures could then be linked into publicly available figures on commercialization (e.g., AUTM, 2000). Some researchers may be especially interested in examining our final proposition that university involvement in technology transfer does not result in a reduction in the quantity and quality of basic research. Concern regarding a possible tradeoff between basic research and UITT has been heightened by recent cutbacks in basic research in the private sector (e.g., IBM, Bell Labs). We are just beginning to understand the managerial and policy implications of the growth of UITT.

Acknowledgements

We thank Stephen Green, Nicholas Argyres, Susan Helper, Adam Jaffe, and Julia Liebeskind, and three anonymous referees for their insightful comments and suggestions. We are also deeply indebted to the many administrators, scientists, managers, and entrepreneurs who agreed to be interviewed. Martha Cobb and Melissa Zidle provided capable research assistance. Financial support from the Alfred P. Sloan Foundation and the NBER is gratefully acknowledged.

References

Adler, N.J., 2002. International Dimensions of Organizational Behavior, fourth ed. South-Western, Cincinnati, OH.

Agmon, T., Von Glinow, M., 1991. Technology Transfer in International Business. Oxford University Press, Oxford, UK.

Allen, T.J., 1984. Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information within the R&D Organization. MIT Press, Cambridge, MA.

N.S. Argyres, J.P. Liebeskind. Privatizing the intellectual commons: universities and the commercialization of biotechnology. Journal of Economic Behavior and Organization, 35 (1996), pp. 427–454

Association of University Technology Managers (AUTM). 2000. The AUTM Licensing Survey, Fiscal Year 1999.

D. Blumenthal, E.G. Campbell, M.S. Anderson, N. Causino, K.S. Louis. Withholding research results in academic lifescience: evidence from a national survey of faculty. Journal of The American Medical Association, 277 (1996), pp. 1224–1228

K. Butterfield, L. Trevino, G. Ball. Punishment from the manager's perspective: a grounded investigation and inductive model. Academy of Management Journal, 39 (6) (1996), pp. 1479–1512

Bryman, A., 1989. Qualitative Research Methods and Organization Studies. Unwin Hyman, London.

W.M. Cohen, D. Levinthal. Absorptive capacity: a new perspective on innovation and learning. Administrative Science Quarterly, 35 (1990), pp. 128–152

J.S. Coleman. Social capital in the creation of human capital. American Journal of Sociology, 94 (1988), pp. 95–120

D.J. Dougherty. Interpretive barriers to successful product innovation in large firms. Organization Science, 3 (1992), pp. 179–203

K.M. Eisenhardt. Making fast strategic decision in high-velocity environments. Academy of Management Journal, 32 (1989), pp. 543–576

M. Feldman, I. Feller, J. Bercovitz, R. Burton. Equity and the technology transfer strategies of American research universities. Management Science, 48 (2001), pp. 105–121

C.S. Fleisher, J.R. Nickel. Attempting TQM in organizational staff areas: TQM as managerial innovation in corporate affairs. Canadian Journal of Administrative Sciences, 12 (1995), pp. 116–127

Friedman, J., Silberman, J., 2003. University technology transfer: the impact of organization and environment, Journal of Technology Transfer 28, 17–30.

H.I. Fusfeld. New global sources of industrial research. Technology in Society, 17 (1995), pp. 263–277

General Accounting Office, 1998. Technology Transfer: Administration of the Bayh-Dole Act by Research Universities. US General Accounting Office, Washington, DC.

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

Y.S. Lee. The sustainability of university-industry research collaboration. Journal of Technology Transfer, 25 (2000), pp. 111–133

J.P. 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

Link, A.N., Scott, J.T., 2003. The growth of research triangle park. Small Business Economics 20, 167–175.

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, 12 (1985), pp. 157–158

R.K. Merton. Priorities in scientific discovery: a chapter in the sociology of science. American Sociological Review, 22 (1957), pp. 635–639

Miles, M.B., Huberman, A.M., 1994. Qualitative Data Analysis, second ed. Sage Publications, Thousand Oaks, CA.

D.C. Mowery, R.R. Nelson, B. Sampat, A.A. Ziedonis. The growth of patenting and licensing by U.S. universities: an assessment of the effect of the Bayh-Dole act of 1980. Research Policy, 30 (2001), pp. 99–119

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

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

E.B. Roberts. Managing invention and innovation: what we've learned. Research Technology Management, 31 (1988), pp. 11–29

Siegel, D., Waldman, D.A., Link, A., 2003. 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, Research Policy 32, 27–48.

J.G. Thursby, R. Jensen, M.C. Thursby. Objectives, characteristics and outcomes of university licensing: a survey of major U.S. universities. Journal of Technology Transfer, 26 (2001), pp. 59–72

M. Tushman. Special boundary roles in the innovation process. Administrative Science Quarterly, 22 (1977), pp. 587–605

D.A. Waldman, T. Lituchy, M. Gopalakrishnan, K. Laframboise, B. Galperin, Z. Kaltsounakis. A qualitative analysis of leadership and quality improvement. Leadership Quarterly, 9 (1998), pp. 177–201

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