Assessing the Impact of Organizational Practices on the Productivity of University Technology Transfer Offices: An Exploratory Study

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ABSTRACT

We present quantitative and qualitative evidence on the productivity of university technology transfer offices (TTOs). Our empirical results suggest that TTO activity is characterized by constant returns to scale and that environmental/institutional factors explain some of the variation in performance. Productivity may also depend on organizational practices. Unfortunately, there are no data on such practices, so we rely on inductive, qualitative methods to identify them. Based on 55 interviews of entrepreneurs, scientists, and administrators at five research universities, we conclude that the most critical organizational factors are faculty reward systems, TTO staffing/compensation practices, and cultural barriers between universities and firms.

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I. INTRODUCTION

Universities have been criticized in some circles for being more adept at developing new technologies than moving them into private sector applications. This is potentially problematic since success in university/industry technology transfer (henceforth, UITT) could be a critical factor in sustaining the global competitiveness of U.S. firms. Some federal agencies have responded to this concern by providing incentives for universities to form partnerships with firms.[1] Expectations regarding a quicker commercial "payoff" to basic research have risen accordingly. To build political support for their institutions, university leaders frequently cite the role of technology transfer in stimulating local economic development. Facing tighter budgets, these administrators often promise to deliver more "bang for the buck" in technology transfer. The private sector has also chimed in, expressing frustration with obstacles that impede the process of commercialization, such as disputes that arise with the university regarding intellectual property rights.

These concerns have raised the visibility of UITT in the public policy arena. In recent years, universities have attempted to formalize UITT and capture a larger share of the economic rents associated with technological innovation by establishing technology transfer offices (henceforth, TTOs). TTOs facilitate technological diffusion through the licensing to industry of inventions or intellectual property resulting from university research. Many institutions established a TTO in the aftermath of the University and Small Business Patent Procedures Act of 1980, otherwise known as the Bayh-Dole Act.

[1] For instance, as noted in Cohen et al. (1998), NSF has established Science and Technology Centers and other programs that require universities to attract matching funds from industry.

Bayh-Dole dramatically changed incentives for firms and universities to engage in UITT. It simplified the UITT process by instituting a uniform patent policy and removing many restrictions on licensing. Furthermore, it allowed universities to own the patents that arise from federal research grants. The framers of Bayh-Dole asserted that a streamlined federal UITT policy and university ownership and management of intellectual property would accelerate commercialization because universities would now have greater flexibility in negotiating licensing agreements and firms would be more willing to engage in them.[2]

It appears that Bayh-Dole has indeed resulted in a more rapid rate of technological diffusion. According to the Association of University Technology Managers (AUTM (1997)), the annual number of patents granted to U.S. universities surged from about 300 in 1980 to approximately 2,000 in 1996, while licensing of new technologies has increased almost twofold since 1991. Annual streams of revenue accruing from these licenses have risen from about \$160 million in 1991 to \$611 million in 1997, now constituting about 2.5% of university R&D expenditures (GAO (1998)). Major products in a wide variety of industries have been developed through UITT, such as the Boyer-Cohen “gene-splicing” technique that launched the biotechnology industry, diagnostic tests for breast cancer and osteoporosis, internet search engines, music synthesizers, computer-aided design (CAD), and environmentally-friendly technologies.

Despite the potential importance of UITT as a mechanism for generating local technological spillovers and as a source of revenue to the university, there is little systematic

[2] “We came to the realization that this failure to move from abstract research into useful commercial innovation was largely a result of the government’s patent policy and we sought to draft legislation which would change this policy

empirical evidence on any dimension of the performance or productivity of UITT activity. The purpose of this paper is to fill this void.

Our measures of relative productivity are constructed from benchmarking surveys conducted by AUTM for the years 1991-1994. We adjust these estimates of relative efficiency to reflect environmental and institutional factors that can influence the rate of technological diffusion at a given university. We postulate that relative performance in UITT may also depend on organizational practices in university management of intellectual property, which potentially attenuate palpable differences in the motives, incentives, and organizational cultures of the parties to licensing agreements (university administrators/TTO directors, managers/entrepreneurs, and academic scientists).

Unfortunately, there are no existing data on such practices, nor is it precisely clear which organizational factors are most critical to effectiveness in UITT. Therefore, we rely on inductive, qualitative methods (field research) to identify these variables, which are typically ignored in conventional productivity studies. The field research also provided a useful reality check on the specification of our econometric model. Accordingly, we conducted 55 structured, face-to-face interviews of UITT stakeholders (15 administrators, 20 managers or entrepreneurs, and 20 scientists affiliated at five universities). We sought feedback from these individuals on the nature of the UITT "production process," the barriers to effective UITT, recommendations to improve the process, and the importance of networks and relationships in UITT.

The remainder of this paper is organized as follows. In Section II, we describe a set

in a way to quickly and directly stimulate the development and commercialization of inventions" (Bayh (1996)).

of internal and external factors that influence the extent of UITT activity at a given university. Differences in the actions, motives, and organizational environments of the parties to licensing agreements are also considered. We conjecture that these differences can potentially undermine efforts to commercialize university-based technologies. This discussion serves to underscore the potential importance of organizational practices as a determinant of the extent of UITT activity at a given university. Section III outlines the method for assessing the relative productivity in UITT. Preliminary empirical results are presented in Section IV. Section V describes our qualitative research design and methods. Section VI presents the qualitative findings. The final section consists of preliminary conclusions and suggestions for additional research.

II. DETERMINANTS OF UITT

Internal Inputs

Figure 1 presents a schematic of the process of the transfer of a technology from a university to a firm or entrepreneur, through the negotiation of a licensing agreement. It also identifies the three key stakeholders involved at each stage of the transfer: academic scientists, TTO personnel/university administrators, and firm/entrepreneurs.

The first stage of the process is scientific discovery. According to the Bayh-Dole Act, the scientist is then required to file an invention disclosure with the TTO. Our field research, which is described in greater detail in Sections V and VI, revealed that this rule is rarely enforced. Thus, TTO personnel must spend a portion of their time encouraging faculty members to disclose inventions.

Once the invention is formally disclosed, the TTO must simultaneously evaluate the commercial potential of the technology and decide whether to patent the innovation. Often, interest in the technology by an industry partner provides sufficient justification for filing a patent. In other instances, the TTO must make these judgements before industry expresses an interest in the technology. Furthermore, universities must decide whether to seek *global* or *domestic* patent protection. Domestic protection is substantially cheaper, but often much less valuable to potential licensees, particularly when foreign markets are perceived to be highly lucrative relative to the U.S. market. As confirmed in our interviews, this decision poses a dilemma for many TTOs because they have limited resources for filing patents.

If the patent is awarded, the TTO will often attempt to market the technology. Faculty members are frequently involved in the marketing phase because they are often in a good position to identify potential licensees and because their technical expertise often makes them a natural partner for companies that wish to commercialize the technology. It is important to note that Figure 1 potentially overstates the role of patents in UITT. As reported in Jensen and Thursby (1998) and confirmed in our field research, many firms will frequently license a technology before it is patented. Furthermore, according to AUTM, university technology managers tend to view patents both as an input and output of UITT.[3] This implies that the key "raw material" in UITT is the invention disclosure. Invention disclosures constitute the pool of available technologies for licensing.

[3] See AUTM (1997) pp. 20-21.

The final stages of UITT involve the negotiation of a licensing agreement with firms or individual entrepreneurs. These agreements could include such benefits to the university as royalties, "follow-on" sponsored research agreements, or an equity stake in a new venture based on the licensed technology. We discovered on our field visits that many universities, especially public institutions, are quite sensitive to the charge that they are "giving away" university-based, taxpayer-funded technologies that yield substantial windfall profits. As a result, many TTOs are adopting a hard line in licensing negotiations.

Interviews with university administrators revealed that TTO involvement does not end with the licensing agreement. It is quite common for TTOs to devote substantial resources to the maintenance and renegotiation of licensing agreements. This is attributed both to the embryonic nature of the technologies and to the fledgling nature of many of the firms that license university-based technologies.

We wish to stress that our qualitative analysis greatly improved our ability to model the "production process" of UITT, by helping us identify the appropriate set of outputs and inputs to include in the production function. For instance, we began this project with the view that there are multiple outputs of UITT. Discussions with university administrators, the "producers" in our model, revealed that licensing activity is by far the most critical output, so we have now focused our attention on this critical dimension of UITT performance. Our qualitative work also revealed that we had greatly underestimated the importance of faculty involvement or "buy-in" to UITT. This stemmed, in part, from our literal interpretation of the language contained in the Bayh-

Dole Act. As noted earlier, Bayh-Dole stipulates that faculty members working on federal research grants must disclose their inventions to the TTO. During our interviews, however, we discovered that this provision is rarely enforced, so that disclosure is actually not mandatory.

Thus, invention disclosures are essentially an intermediate input. The number of disclosures will depend, to some extent, on the efforts of the TTO to elicit disclosures and faculty interest in UITT. This, of course, raises the critical issue of organizational incentives for faculty and TTO personnel to engage in these activities. Consistent with the findings of recent theoretical and empirical studies summarized in Lazear (1999), we hypothesize that human resource management and other organizational practices that influence such incentives could explain some of the variation in UITT performance across universities.

In sum, our analysis reveals that the following internal factors should be considered (internal) inputs of UITT: invention disclosures (a proxy for the set of available technologies), labor employed by the TTO, and (external) legal fees incurred to protect the university's intellectual property.[4]

Environmental/Institutional Variables

University licensing activity may also depend on a vector of environmental and institutional variables. For instance, the presence of a medical school on campus and the

[4] This amount includes expenditures in support of prosecution, maintenance, litigation, and interference costs relating to patents and/or copyrights (see AUTM (1997)).

public status of the university may be important institutional factors. Pressman et al. (1995) report that over 60% of university licenses result from a biomedical invention. Public universities may have less flexible UITT policies than private universities regarding the formation of startup companies and interactions with private firms. Furthermore, public universities may be less focused on UITT as a source of revenue than private universities. An example of an environmental variable is a measure of state-level economic growth, which can be viewed as a proxy for the ability of firms in the local region to sponsor R&D projects at the university.

In explaining the relative efficiency of TTOs, it may also be important to control for the R&D activity of local firms. A plethora of recent studies provide support for the notion that university research generates local technological spillovers. Bania, Eberts, and Fogarty (1993) find that there is a positive relationship between university R&D and the number of firm startups in the same SMSA. Jaffe, Trajtenberg, and Henderson (1993) report that patents (new technologies) generated within the same state (and SMSA) are more likely to be cited by firms in the same state or SMSA. Zucker, Darby, and Brewer (1998), Zucker and Darby (1996), and Audretsch and Stephan (1996) directly examine interactions between academic scientists and local firms and find that these formal and informal linkages play an important role in promoting innovation in biotechnology.

Organizational Factors

An understanding of the potential importance of organizational practices begins with a consideration of the actions, motives, and organizational cultures of UITT stakeholders. As shown in Table 1, we assert that 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. This is an especially strong motive for untenured faculty members. Other possible motives include financial gain and a desire to secure additional funding for graduate assistants, post-doctoral fellows, and laboratory equipment/facilities. The norms, standards, and values of scientists reflect an organizational culture that values creativity, innovation, and especially, an individual's contribution to advances in knowledge (basic research).

The TTO must work with scientists and managers or entrepreneurs to structure a deal. We hypothesize that the primary motive of the TTO is to protect and market the university's intellectual property. Secondary motives include promoting technological diffusion and securing additional research funding for the university via royalties, licensing fees, and sponsored research agreements. Recall that a primary reason for the federal government's relinquishment of intellectual property rights, as stipulated in Bayh-Dole, was to accelerate the commercialization of university-based technologies. Many managers and scientists remarked that TTOs were especially committed to their role as guardian of the university's intellectual property. As such, technology licensing officers tend to be somewhat inflexible and conservative in structuring deals. This inflexibility is consistent with

the bureaucratic organizational culture of the university.

Firms and entrepreneurs seek to commercialize university-based technologies for financial gain. They are also concerned about maintaining proprietary control over these technologies, which can potentially be achieved through an exclusive worldwide license. The entrepreneurial organizational culture of most firms (especially startup companies and high tech firms) rewards timeliness, speed, and flexibility. Reflecting the values of this culture, a number of the managers we visited with stressed the importance of "time to market" as a determinant of success in UITT, in part, because they are convinced that there are significant first mover advantages in high technology markets.

It is apparent from Table 1 that there are palpable differences in the motives, incentives, and organizational cultures of UITT stakeholders that could potentially impede technological diffusion. Therefore, we hypothesize that some of the variation in UITT performance across universities can be attributed to organizational behaviors that potentially help to resolve these differences. Our inductive, qualitative analysis, described in Sections V and VI, will help us identify these factors.

III. ASSESSING RELATIVE PRODUCTIVITY IN UITT

In the previous section, we identified a set of potential determinants of UITT, which be can expressed in equation form as:

(1) UITT = f (**INT, ENV, ORG**)

where **INT** denotes a vector of internal inputs used to generate UITT output, **ENV** represents a vector of environmental and institutional variables, **ORG** is a vector of organizational practices.

To assess relative productivity in UITT, we use the stochastic frontier estimation (henceforth, SFE) methodology developed by Aigner, Lovell, and Schmidt (1977) and Meeusen and Van den Broeck (1977). SFE generates a production (or cost) frontier with a stochastic error term that consists of two components: a conventional random error ("white noise") and a term that represents deviations from the frontier, or relative inefficiency.

SFE can be contrasted to data envelopment analysis (DEA), a non-parametric estimation technique that has also been used extensively to compute relative productivity in service industries (see Charnes et al. (1994)). Thursby and Kemp (1998) use DEA to assess the relative efficiency of university TTOs. DEA and SFE each have key strengths and weaknesses. DEA is a mathematical programming approach that does not require the specification of a functional form for the production function. It can also cope more readily with multiple inputs and outputs than parametric methods. On the other hand, DEA models are deterministic and highly sensitive to outliers. SFE allows for statistical inference but requires restrictive functional form and distributional assumptions. We believe that SFE and DEA should be viewed as complements, not substitutes.

In SFE, a production function of the following form is estimated:

$$(2) \quad y_i = \mathbf{x}_i\beta + \epsilon_i$$

where the subscript i denotes the ith university, y represents output, **x** is a vector of inputs, β is the unknown parameter vector, and ϵ is an error term with two components, $\epsilon_i = V_i - U_i$, where U_i represents a non-negative error term to account for technical inefficiency, or failure to produce maximal output, given the set of inputs used. V_i is a symmetric error term that accounts for random effects. The standard assumption (see Aigner, Lovell, and Schmidt (1977)) is that the U_i and V_i have the following distributions: $U_i \sim$ i.i.d. $N^+(0,\sigma^2_u)$, $u_i \geq 0$

$V_i \sim$ i.i.d. $N(0,\sigma^2_v)$

That is, the inefficiency term (U_i) is presumed to have a half-normal distribution, which indicates that universities are either "on the frontier" or below it. An important parameter in this model is $\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$, the ratio of the standard error of technical inefficiency to the standard error of statistical noise, which is bounded between 0 and 1. Note that $\gamma = 0$ under the null hypothesis of an absence of inefficiency, signifying that all of the variance can be attributed to statistical noise.

In recent years, SFE models have been developed that allow the technical inefficiency term to be expressed as a function of a vector of environmental and organizational variables. This is consistent with our notion that deviations from the frontier (which measure relative inefficiency in UITT) are related to institutional and organizational factors. Following Reifschneider and Stevenson (1991), we assume that the U_i are independently distributed as truncations at zero of the $N(m_i,\sigma^2_u)$

distribution with

$$(3) \quad m_i = \mathbf{z}_i \delta$$

where **z** is a vector of environmental, institutional, and organizational variables that are hypothesized to influence efficiency and δ is a parameter vector.[5]

Following Battese and Coelli (1995), we derive maximum likelihood estimates of the parameter vectors β and δ from simultaneous estimation of the production function and inefficiency term equations, using the FRONTIER statistical package (See Coelli (1994)). Based on these parameter values, we will compute estimates of relative productivity.

Our empirical specification of equation (2) is based on the knowledge production function framework developed by Griliches (1979), here extended to university licensing, our proxy for UITT output. We assume a three-factor, log-linear Cobb-Douglas production function, relating licensing to three inputs: invention disclosures, TTO staff, and legal expenditures:

$$(4) \ln(LICENSE_i) = \beta_0 + \beta_1 \ln(INVDISC_i) + \beta_2 \ln(STAFF_i) + \beta_3 \ln(LEGAL_i) + V_i - U_i$$

where LICENSE = average annual licensing agreements or revenue
INVDISC = average annual invention disclosures
STAFF = average annual TTO employees
LEGAL = average annual external legal expenditures

with the technical inefficiency (U_i) term expressed as:

$$(5) U_i = \delta_0 + \sum_k \delta_k \mathbf{ENV_i} + \sum_m \phi_m \mathbf{ORG_i} + \mu_i$$

[5] Battese and Coelli (1995) have recently extended this model to incorporate panel data.

where **ENV** and **ORG** are defined as in equation (1) and μ is a classical disturbance term. As noted in the previous section of the paper, we do not have systematic measures of **ORG**. The equation we actually estimate contains only the following environmental and institutional factors:

$$(5a) U_i = \delta_0 + \delta_M MED_i + \delta_P PUBLIC_i + \delta_R INDRD_{ij} + \delta_Q INDOUT_{ij} + \mu_i$$

where MED and PUBLIC are dummy variables denoting whether the university has a medical school and whether it is a public institution, respectively; and INDRD and INDOUT are average annual industry R&D intensity and average annual real output growth in the university's state (j), respectively, during the sample period.[6]

The characteristics of our data and parameter estimates of equations (4) and (5a) are presented in the following section.

IV. DATA and RESULTS

Our primary data source is a comprehensive survey conducted by AUTM. The survey was completed by TTO directors at 183 academic institutions for the years 1991-1994. We eliminated teaching hospitals, research institutes, and Canadian institutions, leaving us with 113 U.S. universities. This is by no means a random sample of research universities, as evidenced by the fact that 80 out of 89 U.S. "Research 1" institutions are included in our final sample.[7]

[6] An alternative is to use MSA-level R&D data on industrial innovations and R&D employment, provided in Anselin, Varga, and Acs (1997). Unfortunately, these data (from 1982) do not correspond to our sample period.
[7] Source: Carnegie Foundation for the Advancement of Teaching-To qualify for Research 1 status, a university must award 50 or more doctoral degrees and receive at least $40 million annually in federal research grants.

The AUTM file contains annual data on the number of licensing agreements (LICENSE1), royalty income generated by licenses (LICENSE2), invention disclosures (INVDISC), number of full-time-equivalent employees in the TTO (STAFF), and legal expenditures on UITT (LEGAL). Our data sources for state-level industrial R&D (INDRD) and real output growth (INDOUT) are NSF and the BEA.[8]

Several difficulties with the output data should be noted. First, licensing agreements vary substantially in their significance, making it dangerous to draw inferences about aggregate technology flows based on the number of deals.[9] To address this concern, we use licensing revenue as an additional measure of output. Another limitation is that we focus only on two UITT outputs: (1) licensing agreements and (2) royalties. Sponsored research and the formation of startup companies can also be viewed as outputs of UITT. However, it is important to note that startups and sponsored research agreements are often corollaries to licensing agreements. Along similar lines, one could also assume a broader view of technology transfer and consider patents, invention disclosures, and even students as UITT outputs. Given the uncertainty surrounding this issue, we asked UITT stakeholders to identify the outputs of UITT in our field research.

Descriptive statistics for the inputs and outputs of the licensing production

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[8] Source: NSF-Research and Development in Industry (1991-1994), U.S. BEA (1999)-Gross State Product data reported in Fixed Reproducible Tangible Wealth.

[9] A similar problem is encountered with patents. Jaffe, Trajtenberg, and Henderson (1993), Trajtenberg, Henderson, and Jaffe (1997) and Henderson, Jaffe, and Trajtenberg (1998) weight patents on the basis of the number of

function are presented in Table 2. The average university in our sample generates 12 licensing agreements per year, earns $1.6 million in licensing income, generates 46 invention disclosures, employs eight workers in the TTO, and spends $300,000 on external legal fees to protect its intellectual property.

Table 3 contains two sets of parameter estimates of the stochastic frontier production function and inefficiency models outlined in the previous section (equations (4) and (5a)) for two dependent variables: average annual number of licensing agreements and average annual licensing revenues, respectively. Columns (1) and (4) present OLS results, which are used to obtain starting values for the regression parameters in the SFE model.[10] Columns (2) and (5) contain maximum-likelihood estimates of the SFE model without the environmental and institutional variables, while Columns (3) and (6) present the coefficients of the “full” version of the SFE model, including the inefficiency model with environmental and institutional variables.

The production function model appears to fit quite well, based on the R^2 values. Across all variants, the estimated elasticity of licensing output with respect to invention disclosures is positive and highly significant. The results also imply that hiring more staff in the TTO results in more licensing agreements (columns (1)-(3)), but not additional licensing revenue (columns (4)-(6)). This result suggests that university administrators have established TTO incentives in a manner that is

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citations they receive.

[10] Coelli (1994) points out that, except for the intercept term, the OLS estimates are consistent, albeit inefficient.

consistent with the spirit of Bayh-Dole, i.e., to maximize the number of licensing agreements.

On the other hand, the findings imply that spending more on (external) lawyers reduces the number of licensing agreements, but increases licensing revenue. One interpretation of this result is that using outside lawyers provides a signal that the university is aggressively protecting its intellectual property. This results in fewer, but more lucrative, licensing agreements. Of course, it is difficult to assess the validity of this hypothesis without additional information on the composition of the TTO staff. That is because substantial external legal expense could actually reflect outsourcing of legal functions or defensive actions in the aftermath of a major lawsuit.

The F statistics imply that the production process for licensing agreements is characterized by constant returns to scale. This finding is consistent with the results of a recent study by Adams and Griliches (1996). The authors examined the research productivity of universities, using papers and citations as outputs and R&D expenditures as inputs, and found evidence of constant returns to scale.

It appears that licensing revenue, on the other hand, is subject to increasing returns. An implication of this finding is that a university employing a revenue maximization strategy should spend more on lawyers. Perhaps this would free up TTO staff to spend more time "matching" scientists to firms. These results should be interpreted with caution because licensing revenue, even when computed over a four-

year period, can be a somewhat misleading indicator of the current performance of a TTO, because royalty streams may reflect transactions that were consummated many years ago. For instance, the University of Florida has consistently ranked among the top 10 U.S. universities in licensing income due to Gatorade.

Next, we focus on parameter estimates of the "full" SFE model (SFE2), including the inefficiency equation (eq. (5a)). For the most part, the coefficients on the environmental and institutional variables have the appropriate signs, but are uniformly insignificant. The findings do imply, however, that universities in states with higher levels of industrial R&D activity are less inefficient, that is, closer to the frontier. Thus, our evidence suggests that there may be an association between R&D conducted by local private firms and UITT activity at research universities in the same state. Despite the lack of significance of many of the individual coefficients, the γ values are highly statistically significant, indicating that the (null) hypothesis that inefficiency effects are absent from the model can be decisively rejected.

Further evidence that external factors provide some explanatory power is shown on the bottom of Table 3, which contrasts the mean technical efficiency in the versions of the model excluding (columns (2) and (5)) and including (columns (4) and (6)) the environmental and institutional variables. The latter set of findings indicate that these external factors explain some of the variation in technical inefficiency across universities, 20.8% and 15.4%, respectively.[11]

As noted in the previous section, we hypothesize that some of the variation in relative productivity can also be attributed to organizational practices in university management of intellectual property. These practices could potentially serve to mitigate conflict caused by palpable differences in the motives, incentives, and organizational cultures of scientists, firms, and administrators. Unfortunately, there are no existing data on organizational practices in UITT, nor is it even precisely clear what needs to be measured.

Accordingly, we outline our inductive, qualitative approach to the examination of organizational issues in the next section of the paper. We also provide detailed information on qualitative research methods as they relate to field studies, given that most economists are unfamiliar with these techniques. This information may also be beneficial to economists who are contemplating fieldwork.

V. Qualitative Research Methods-Field Studies

As shown in Table 4, a researcher who wishes to conduct an interview-based, field study confronts four key methodological issues:[12]

1) Sample Selection
2) Nature of Interview Questions
3) Procedures for Conducting Interviews
4) Qualitative Data Analysis

[11] That is, the mean technical efficiency is closer to one when we include these variables in the stochastic frontier model (.05/(1 - .76) =.208 and .04/(1 - .74)) =.154).

[12] This is by no means an exhaustive list of such concerns. For a comprehensive review of qualitative research methods, see Miles and Huberman (1994) and Yin (1989).

That is, in designing the qualitative component of this study, we had to select an appropriate sample of organizations and individuals to visit, formulate a set of interview questions, determine how to conduct the interviews, and choose an appropriate method for analyzing the qualitative data (from the interviews). Table 4 summarizes how we addressed each of these issues. In doing so, we borrowed heavily from long-standing literatures in the fields of management, psychology, and sociology, where qualitative methods are prevalent.

To assess the nature and relevance of organizational factors in UITT, we interviewed TTO stakeholders affiliated with five research universities in the Southwest and Southeast. This clearly constitutes a convenience sample of universities because of our familiarity with these institutions and the surrounding regions. However, as noted in Yin (1989), convenience samples of organizations are common in inductive, exploratory studies, especially when researchers have limited funding.

Note that our focus on these two regions precludes an examination of major hubs of technology transfer activity, such as Cambridge/Boston (MIT, Harvard, and Boston University) or the San Francisco Bay area (Stanford and UC-Berkeley). We contend, however, that the schools we visited are probably far more representative of the modal university experience with technology transfer, as compared to top-tier schools that have more favorable environmental conditions for promoting the commercialization of university R&D.

Table 5 presents some information on the characteristics of the five universities that we examined. Our sample consists of 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, the extent of licensing activity, and relative productivity (technical efficiency).[13] Note also that each of these schools established a TTO soon after the enactment of Bayh-Dole (1980).

Returning to the issues outlined in Table 4, another sample selection concern is the representativeness of the interviewees. Recall that our goal is to examine what may be three different perspectives on UITT organizational issues (scientists, administrators, and managers/entrepreneurs). Given this objective, we attempted to draw a sample of respondents that best reflected representative attitudes of these stakeholder groups.

Potential respondents were selected in two ways. First, we identified the TTO director and other administrators with UITT responsibilities, such as a Vice Provost, Vice President, or Vice Chancellor for Research.[14] Second, to identify managers/entrepreneurs and scientists, we solicited feedback from two nonprofit organizations that serve as technology transfer "facilitators" in each region. By design, these facilitators have a balanced view on UITT. Furthermore, they are well connected to all UITT stakeholders because they have interacted extensively

[13] That is, some institutions are close to the frontier, while others are highly inefficient.
[14] Typically, the TTO director reports to a Vice President, Vice Provost, or Vice Chancellor for Research.

with them. These facilitators helped us select managers and scientists with different perspectives on UITT.[15]

In sum, a stratified approach (Miles and Huberman (1994)) was used for the selection of interviewees, so that they would be drawn from each of the constituent groups described above. At each of the five universities, we conducted interviews with academic scientists, TTO directors, and high-level university administrators who oversee the TTO. Within the surrounding region of the university we also met with founders of startup firms, directors of business development, intellectual property managers and other research executives of large companies, and executives of patent management firms and nonprofit organizations with an interest in UITT. We conducted 55 interviews: 20 managers/entrepreneurs, 15 administrators (5 TTO directors and 10 top-level administrators), and 20 scientists. Although there were only 55 face-to-face meetings, we actually interviewed 98 individuals, since multiple respondents were present at some meetings.

Another methodological issue concerns the nature of the interview questions. In formulating our list of questions, we adopted a "semi-structured" approach, as suggested by Miles and Huberman (1994), whereby interviewees within each of three stakeholder categories were asked the same questions. According to these authors, the best approach for an inductive study is to ask <u>open-ended</u> questions, such as "What are the outputs of UITT?," "What are the

[15] In one region, a facilitator had published a voluminous report on UITT, which contained the names, phone numbers, and addresses of these potential respondents.

barriers to effective UITT?," and "How would you improve the process?" We asked such questions to all stakeholders (scientists, administrators, managers, and entrepreneurs), although some queries were tailored to a particular group. For example, TTO directors were asked about managerial practices in the TTO; administrators were asked broader questions about the university's strategic goals for UITT.

As shown in Table 4, we also had to establish interview procedures. Sekaran (1992) contends that face-to-face interviews are best when conducting an inductive study on a controversial topic. She notes that in-person interviews offer several advantages. First, it is often easier to clarify questions and sense any discomfort on the part of a respondent in a face-to-face interview, rather than by telephone. Second, qualitative researchers report that eye contact often elicits more accurate and comprehensive information because it can raise the interviewee's comfort level. Eye contact may also help to build trust, which can be important if the issue under consideration is sensitive. Finally, there may also be a guilt effect. That is, interviewees may feel obliged to "reward" researchers who have traveled long distances to visit them by providing more candid and provocative information.

To further improve the quality of information collected during the interviews, we employed a team approach, by pairing an economist with a management

professor.[16] Although the two economists on this paper have previously conducted field studies (Link and Scott (1998) and Siegel (1999)), management professors have much more extensive experience and training in qualitative research techniques. Economists who are contemplating fieldwork should draw on the expertise of colleagues in other disciplines. Also, the use of teams (regardless of expertise) can enhance the overall effectiveness of a face-to-face interview by increasing the likelihood that a researcher can respond to a clarifying question or establish a rapport with the interviewee.

Following Waldman et al. (1998), we also employed three tactics in conducting our interviews that have been shown to increase the accuracy and reliability of qualitative data. The first is neutral probing of answers, to avoid unduly influencing the respondent when following up on a response to an open-ended question. Second, we provided a pledge of confidentiality, to increase the likelihood that interviewees provide candid and forthright responses. Finally, each interviewee had prior knowledge of the goals of our study and the credentials of the interviewers. According to Yin (1989), this serves two useful purposes. First, it indicates the researchers' concern and respect for the value of the respondent's time. Second, it reduces uncertainty and suspicion regarding the intentions of the researchers.

The final methodological issue is qualitative data analysis, or how to

[16] 5 professors (2 management professors and 3 economists) conducted the 55 interviews (see Siegel et al. (1999)).

organize, examine, and display the information we collected during the lengthy interviews, which lasted, on average, for about one hour. Not surprisingly, there was considerable variation in the duration of interviews, given the open-ended nature of the questions. Interviews were tape recorded and then transcribed by a third (clerical) party. Eisenhardt (1989) contends that a third-party transcription ensures a complete and unbiased recording of interview data.[17]

Once we generated the 55 transcripts, we implemented the three stages of qualitative analysis of interview data outlined in Miles and Huberman (1994).[18] These are data reduction, data display, and conclusion drawing/verification. Data reduction involves the selection, simplification, and transformation of raw data (interview responses) into an analyzable form. The first step was the development of a list of general categories for content analysis. These categories were largely based on general research questions, such as identifying the barriers to UITT.

As demonstrated by Miles and Huberman (1994), it is common for coding categories to be modified because of a poor fit or the need to add and combine classifications. Indeed, an initial review of fifteen transcripts indicated that comments relevant to one of our initial categories (i.e., aspects of the TTO) should be combined with other categories. We also followed the advice of Miles and Huberman (1994) by having multiple assessors of interview transcripts. The authors assert that the use of multiple assessors reduces the degree of bias in

[17] Following Bryman (1989), interviewees were also promised a study report of aggregated findings.

interpreting such transcripts.

Thus, for each transcript, all comments were independently categorized by at least two members of the research team into four areas: (1) UITT outputs, (2) networks/relationships in UITT, (3) barriers to UITT, and (4) proposed improvements to the UITT process. The 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.[19]

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

After a consensus was reached regarding the themes, 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 frequency counts for each major theme that emerged. In Tables 6-9, we display percentages of respondents who identified a particular theme relating to UITT outputs, relationships/networks, barriers to effective UITT, and suggested improvements to the

[18] See Miles and Huberman (1994), pp. 10-12.
[19] These methods are similar to those employed by Butterfield, Trevino, and Ball (1996), who identified unique "thought units" pertinent to their subject of interest (employee discipline).

UITT process. For example, as shown in the first column on Table 6, seventy-five percent of the managers/entrepreneurs we interviewed identified licenses as an output of UITT. Note that these analyses are conducted separately for each stakeholder group. Proportion tests of differences (Z-tests) were computed to compare whether the proportion of respondents mentioning a theme in a given group differs from the proportion of respondents mentioning a theme in another group. For instance, Z_{12} compares managers/entrepreneurs (Group 1) and TTO directors/university administrators (Group 2).

VI. QUALITATIVE FINDINGS

Table 6 demonstrates that licenses and royalties were identified as outputs of UITT by a substantial majority of TTO directors and university administrators. Managers and entrepreneurs also frequently mentioned licenses, but stressed informal aspects of UITT a bit more, as well the economic development aspects of UITT. Scientists emphasized product development and somewhat surprisingly, failed to mention sponsored research agreements.

Another key finding is that there is considerable heterogeneity in stakeholder perspectives regarding UITT outputs. There appears to be a "Rashomon" effect, as demonstrated by the numerous output categories identified by respondents and by the many significant differences between each class of interviewee (16 out of 30 Z statistics are significant at the 5% level). This result is perhaps not surprising,

given that university management of intellectual property through a TTO is a recent and somewhat controversial development. Some interviewees perceived the mission of the TTO (protection and marketing of the university's intellectual property) as being inconsistent with the traditional "public domain" philosophy regarding the dissemination of information that typically pervades research universities.

As shown in Table 7, respondents in each stakeholder category mentioned *personal* relationships in UITT much more frequently than *contractual* relationships. One scientist phrased it in this manner:

> *"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 formally sponsored by a consortium]"*

This raises the possibility that the formation of "social networks" could be important in UITT. These networks include academic and industry scientists, graduate students and post-doctoral fellows who do most of the experimental work in laboratories, former graduate students who have accepted positions in industry, entrepreneurs, 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, where information is the currency of exchange.[20]

Moreover, in a high technology business context, 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 rapid development and availability of scientific knowledge with relatively low sunk costs, i.e., internal R&D costs. Liebeskind et al. (1996) provided evidence of how the existence of social networks can increase organizational learning and flexibility in biotechnology.

Table 7 also indicates that knowledge transfer appears to work in both directions. Sixty-five percent of the scientists we interviewed noted that interacting with industry has influenced their basic research. Some scientists explicitly mentioned that these interactions improved the quantity and quality of their basic research. A representative comment from a scientist was:

> *"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 means I can conduct more experiments."*

This observation is consistent with the findings of Zucker and Darby (1996), who observed an increase in the scholarly output of "star" academic scientists who become involved in commercialization efforts in biotechnology.[21]

As shown in Table 8, all three groups identified a lack of understanding

[20] Powell (1990) argued that social networks are the most efficient organizational arrangement for sourcing information because information is difficult to price and communicate through a hierarchical structure.

regarding university/corporate/scientific norms as a barrier to effective UITT (90.0%, 93.3%, and 75.0%). It appears that these cultural and informational barriers are pervasive. That is, university scientists and administrators often do not understand or appreciate the industry environment, and vice versa. An illustrative comment from a scientist was:

> *"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."*

Our qualitative evidence is consistent with the view that UITT stakeholders operate under different organizational environments and cultures, which implies that they have different norms, standards, and values. For example, Nelson (1998) noted how universities and firms differ in their perspective on the role of knowledge. Managers and entrepreneurs usually do not share the academic values of publishing results and sharing information with colleagues and the general public. Instead, new knowledge and technology is to be kept proprietary and exploited to achieve or sustain a competitive advantage.

Table 8 also indicates widespread belief that there are insufficient rewards for faculty involvement in UITT. Sixty percent of the university administrators and seventy percent of the scientists reported this as a barrier. In their comments, administrators and scientists specifically referred to two types of (pecuniary and non-pecuniary) rewards: a) tenure and promotion policies and b) the university's royalty and equity

[21] Mansfield (1995) reported similar results for a variety of scientific fields.

distribution formula. The latter 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.[22] An administrator at a university with a relatively low payout rate to inventors noted that:

> *"Some faculty members have complained about the low share of revenue they receive. They may be right. We hope to bring that up to say 40% in the near future. I don't think we'll have much of a struggle on that one."*

The vast majority of interviewees also specifically commented on the fact that tenure and promotion decisions continued to be made almost strictly on the basis of publications and grants. For example, one scientist remarked:

> *"Technology transfer has not played a role in the performance evaluation process. Performance evaluation is based on publications."*

From this scientist's perspective, the existing reward structure at his university is inconsistent with the organizational objective of increasing UITT, a goal that is featured prominently in that university's mission statement and promotional brochures.

Managers/entrepreneurs (80.0%) and scientists (70.0%) also frequently pointed to university bureaucracy and inflexibility as barriers to effective UITT. Many scientists and managers provided us with examples of rigid, cumbersome, and unclear policies and procedures that impede UITT. Faculty members who had

[22] Jensen and Thursby (1998) surveyed 62 TTOs and found that the mean payout rate to inventors is 40%.

tried to form startup companies were especially vocal on this point. A typical remark from a scientist was:

> *"I don't think they 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."*

Staffing practices within the TTO are also a matter of concern. Recall that a university technology licensing officer is responsible for coordinating the activities that result in the consummation of an agreement between the university (and its scientists) and a firm. Fifty-five percent of the managers and entrepreneurs we interviewed expressed dissatisfaction with the marketing and negotiation skills of TTO personnel. An intellectual property manager stated:

> *"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."*

Other respondents noted that TTOs are either too narrowly focused on a small set of technical areas, or too concerned with the legal aspects of licensing.

There is also a strong belief on the part of industry (80.0%) that universities exercise their intellectual property rights too aggressively. Of course, this is not a surprising observation given the inherently adversarial nature of negotiations. 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'."*

Table 9 presents some suggested improvements to the UITT process, as provided by our respondents. These recommendations are fairly consistent with the impediments identified in Table 8. With virtual unanimity, respondents suggested that universities and industry should devote more effort to developing better mutual understanding. Several respondents noted that this could easily be achieved through such events as "Town Hall" meetings involving the three stakeholder groups, as well as by targeting each individual group with additional information to help facilitate UITT. For example, one university scientist pointed out that new faculty orientations at his university did not include a module on technology transfer issues:

> *"It's appalling that new faculty members don't receive any information on how to get involved in technology transfer at their orientation sessions. What does that tell you about this school's priorities?"*

Another consistent theme was that universities should modify reward systems to be consistent with technology transfer objectives. Although we do not have systematic measures of the intensity of feeling regarding a particular theme, our perusal of the transcripts reveals that the recommendations regarding changes in reward systems were by far the most direct and vivid of the suggested improvements to the UITT process. Many university administrators specifically mentioned the need to reward UITT activities more in promotion and tenure decisions. One department chair phrased it as follows:

> *"It's the height of hypocrisy for universities to claim that they value technology transfer, or that it's supposed to be a top institutional priority, and then fail to reward it in their promotion and tenure decisions. At some point, we've got to resolve this*

> *discrepancy."*

More importantly, several managers/entrepreneurs and administrators discussed the need for incentive compensation for university technology managers. A representative comment from a manager was:

> *"The TTO people need to push the deals through … You've got to look at how they are rewarded. Perhaps if they were paid on the basis of the number of deals they complete or the revenue they generate for the university, you would see more technologies licensed. I guess that they are so terrified of negative publicity if a bad deal goes through, that they're afraid to make this change."*

Our respondents noted that some private universities, and even some public institutions, such as the University of Washington and Wayne State University, have recently instituted incentive compensation programs in the TTO. Other universities are known to be contemplating implementing these programs.

Table 9 also demonstrates that, to a lesser extent, there was support for the notion that universities should devote additional resources to UITT, although most of these recommendations were somewhat nebulous. Many respondents also suggested that universities provide more education and/or community outreach to overcome informational and cultural barriers. A predictable recommendation from managers and entrepreneurs is that universities should be less aggressive in exercising intellectual property rights.

VII. CONCLUSIONS AND SUGGESTIONS FOR ADDITIONAL RESEARCH

In this paper, we present quantitative and qualitative evidence on several aspects of UITT. A stochastic production function framework is used to assess the relative productivity of university TTOs. Our parameter estimates of this stochastic frontier imply that licensing activity, our proxy for UITT, is characterized by constant returns to scale. The deviations from the frontier, which represent technical inefficiency, are assumed to be a function of a vector of environmental and institutional variables. We find that these variables do indeed explain some of the variation in relative productivity across universities.

We hypothesize that some of the remaining variation in relative efficiency can be attributed to organizational practices in university management of intellectual property. Unfortunately, this hypothesis cannot be formally tested because there are no systematic measures of these factors. Thus, an analysis of UITT organizational practices is fertile ground for an inductive, exploratory field study. As a first step towards identifying these practices, we conducted 55 face-to-face interviews of key UITT stakeholders at five research universities. We believe that our fieldwork also greatly improved our ability to model the UITT process, by providing a critical reality check on the specification of the econometric model.

The qualitative results imply that the most critical organizational factors are reward systems for faculty involvement in UITT, compensation and staffing practices in the TTO, and actions taken by administrators to extirpate informational and cultural barriers between universities and firms. More specifically, it appears

that the propensity of faculty members to disclose inventions, and thus, increase the “supply” of technologies available for commercialization, will be related to promotion and tenure policies and the university’s royalty and equity distribution formula. TTO compensation practices could also be relevant because UITT activity will depend on the efforts of technology licensing officers to elicit invention disclosures and market them effectively to private companies. Thus, we expect that, ceteris paribus, licensing activity will be higher at universities that have implemented some form of incentive compensation program for technology licensing officers.[23]

Staffing practices in the TTO may also help explain why some universities are proficient than others in managing intellectual property. According to Parker and Zilberman (1993), TTOs usually hire either a mix of scientists and <u>lawyers</u> or a mix of scientists and <u>entrepreneurs/businessmen</u>. In the former case, legal functions, such as the adjudication of disputes involving intellectual property rights and negotiating royalty agreements, are performed in-house. In the latter case, such functions are usually outsourced. Parker and Zilberman suggest that the entrepreneur/business model for TTOs may be more conducive to helping scientists form their own start-ups. It also seems reasonable to assume that TTO s staffed in this manner would be more effective in the marketing phase of UITT. A sizable percentage of the managers we interviewed suggested that universities hire

[23] Lazear (1999) and Ichniowski, Shaw, and Prennushi (1997) report a positive correlation between incentive compensation and worker and plant productivity, respectively.

more licensing professionals with stronger technical and marketing skills.

Our findings regarding informational and cultural barriers suggest that "boundary spanning" could be an important skill for university technology licensing officers. Boundary spanning behavior has been studied extensively in the management literature.[24] In the context of UITT, boundary spanning refers to actions taken by university technology managers to serve as a bridge between "customers" (entrepreneurs/firms) and "suppliers" (scientists), who operate in distinctly different environments. Without effective boundary spanning, the needs of customers may not be adequately communicated to suppliers. Similarly, the capabilities and interests of suppliers may not be adequately communicated to customers. Effective boundary spanning on the part of the TTO would involve adept communication with both stakeholder groups in an effort to forge alliances between scientists and firms.

The most natural extension of our exploratory study would be to survey UITT stakeholders at each university in an attempt to measure the organizational factors we have identified.[25] Some variables, such as the university's royalty and equity distribution formula are easy to measure with a survey and may even be available on the worldwide web. Other variables, such as measures of the skills of TTO personnel, tenure and promotion policies, and other policy variables will be more perceptual in nature. In designing these surveys, we need to mindful of the considerable heterogeneity in stakeholder perspectives on UITT that was revealed in our interviews. This finding

[24] See Caldwell and O'Reilly (1982), and Katz and Tushman (1983).
[25] We can use an existing survey instrument to measure boundary-spanning skills (Caldwell and O'Reilly (1982)).

underscores the importance of surveying scientists, managers/entrepreneurs, and administrators separately to generate a more accurate and unbiased view of the organizational environment.

Taking stock of organizational practices in university management of intellectual property will be useful in several respects. First, given the embryonic nature of the TTO enterprise, there is a need to document the nature of these practices. Many administrators expressed a strong interest in benchmarking their intellectual property management practices relative to peer institutions.

Perhaps the most important benefit of collecting this information is that it can be used to determine the fraction of the variance in relative productivity that can be attributed to organizational practices. We can also identify specific practices that enhance UITT performance. These results could have important managerial and policy implications. Finally, we can use this information to examine the determinants and consequences of the adoption of complementary organizational practices. Recent theoretical (Milgrom and Roberts (1990, 1995) and Athey and Stern (1997)) and empirical (Ichniowski, Shaw, and Prennushi (1997)) studies highlight the importance of clusters or "mixes" of complementary organizational practices in enhancing productivity, due to interaction effects. It would be interesting to see if such synergies arise in the context of UITT.

Finally, we also envision several extensions to the econometric analysis. First, we would like to add some additional environmental and institutional factors as explanatory variables in the inefficiency equation. These include the age of the TTO, a measure of the strictness of state and university technology transfer policies (serving as a proxy for the degree of intellectual property protection at the university), local venture capital activity, and more detailed data on industrial R&D in the local region. Second, with more recent data on UITT outputs and inputs, we could examine whether the efficiency frontier is shifting over time. Given the relatively embryonic nature of the TTO enterprise, it is reasonable to assume that the absolute (mean) level of technical efficiency has risen in recent years, as university administrators learn how to manage intellectual property more effectively. A final extension to our empirical analysis would be include multiple outputs of UITT, such as the number of startups and sponsored research agreements resulting from UITT. This requires a "distance" function approach, which has been implemented in several recent studies in the stochastic frontier literature.[26]

[26] See Lovell (1994) and Grosskopf et al. (1997). This class of models assumes that the relationship between output and inputs can be represented by a transformation function T, where 0=T(**x**,**y**) and **y** denotes a vector of outputs (0=y-f(**x**) for the single output case).

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Table 1

Characteristics of University/Industry Technology Transfer (UITT) Stakeholders

Stakeholder	Actions	Primary Motive(s)	Secondary Motive(s)	Organizational Culture
University Scientist	Discovery of New Knowledge	Recognition within the Scientific Community	Financial Gain and a Desire to Secure Additional Research Funding	Scientific
Technology Transfer Office	Works with Faculty and Firms/ Entrepreneurs to Structure Deal	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	Entrepreneurial

Source: the Authors

Table 2

Descriptive Statistics for Inputs and Outputs of the Stochastic Frontier Production Function (Equation (4))

Variable Name	Description	Mean	Median	Standard Deviation
LICENSE1	Average Annual Licensing Agreements	12.2	6	19.8
LICENSE2	Average Annual Licensing Revenue ($000)	1610.4	294.5	4890.5
INVDISC	Average Annual Invention Disclosures	45.9	24	68.6
STAFF	Average Annual TTO Employees	7.7	4	15.4
LEGAL	Average Annual External Legal Expenditures On UITT (000)	303.7	116.4	631.2

N=113 universities, 1991-1994.

Source: AUTM (1997)

Table 3

Maximum Likelihood Estimates of the Stochastic Frontier and Inefficiency Models (eqs. (4) and (5a))

	Dependent Variable					
	Average Annual # of Licensing Agreements			Average Annual Licensing Revenue		
Stochastic Frontier	(1) OLS	(2) SFE1	(3) SFE2	(4) OLS	(5) SFE1	(6) SFE2
INTERCEPT	-.390**	-.207**	-.312**	2.514*	1.827*	1.432
	(.193)	(.101)	(.154)	(.624)	(.803)	(.621)
INVDISC	.678*	.667*	.642*	1.359*	1.410*	1.231*
	(.085)	(.092)	(.087)	(.273)	(.356)	(.478)
STAFF	.439*	.385*	.391*	-.293	-.244	-.189
	(.093)	(.116)	(.099)	(.301)	(.402)	(.304)
LEGAL	-.057**	-.059**	-.042**	.505*	.480*	.421*
	(.025)	(.029)	(.020)	(.081)	(.112)	(.137)
Inefficiency Model						
MED			-.121			-.087
			(.211)			(.112)
PUBLIC			.021			.036
			(.052)			(.082)
INDRD			-.118**			-.087
			(. 058)			(.067)
INDOUT			-.031			-.049
			(.060)			(.070)
R^2	.815			.734		
F stat for $\beta_1+\beta_2+\beta_3=1$	1.16			9.87*		
Log Likelihood		-21.13	-20.02		-23.02	-21.98
$\gamma = \sigma^2_u / (\sigma^2_v + \sigma^2_u)$		.789*	.682*		.834*	.745*
		(.168)	(.231)		(.341)	(.268)
Mean Technical Efficiency		.76	.81		.74	.78

Notes: Standard errors in parentheses, N=113 universities

* Significant at the 1% level, ** Significant at the 5% level

SFE1-Stochastic frontier estimation excluding environmental/institutional determinants of inefficiency

SFE2- Stochastic frontier estimation including environmental/institutional determinants of inefficiency

Table 4

Four Key Methodological Issues in a Field Study and How We Addressed Them

Sample Selection	Nature of Interview Questions	Procedures for Conducting Interviews	Qualitative Data Analysis
• Convenience Sample Of Five Universities from Two Regions	• Semi-Structured (some questions were the same for each group; some were tailored to a particular group)	• Face-to-Face Interviews	• Tape Recording And Transcription of Interviews by Neutral Third Party
• Stratified Approach to The Selection of Interviewees: → Managers/ Entrepreneurs → University Administrators → University Scientists	• Open-ended Questions	• Team Approach	• Identification of Themes from Transcripts by Multiple Assessors
		• Neutral Probing	• Coding of Themes
		• Pledge of Confidentiality	• Frequency Tables Displaying Important Themes
		• Interviewees Had Prior Knowledge of the Goals of the Study and Backgrounds of the Researchers	• Z-tests Comparing Proportion of Responses Between Stakeholder Groups

Table 5

Characteristics of the Universities in our Field Study

	University A	University B	University C	University D	University E
Organizational Status	Private	Public	Public	Public	Public
Medical School	Yes	Yes	No	No	Yes
Land Grant Institution	No	No	Yes	No	Yes
TTO Established in	1984	1985	1982	1985	1988
STAFF	13.3	10.8	10.0	2.7	8.1
LICENSE1	27.0	15.8	25.8	2.8	12.8
LICENSE2	985.7	567.0	1274.6	344.3	150.8
Technical Efficiency	87.7	81.1	92.9	70.2	79.2

Table 6

Outputs of University/Industry Technology Transfer (UITT) as Identified by Interviewees in Our Field Study

	Type of Interviewee					
Outputs	(1) Managers/ Entrepreneurs	(2) TTO Directors/ Administrators	(3) University Scientists	Z_{12}	Z_{13}	Z_{23}
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	5.0	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 test statistics for differences in mean percentages between each class of interviewee.

** $p < .05$
* $p < .01$

Table 7
Aspects of Relationships/Networks in University/Industry Technology Transfer (UITT) as Identified by Interviewees in Our Field Study

Relationships/ Networks	Type of Interviewee (1) Managers/ Entrepreneurs	(2) TTO Directors/ Administrators	(3) University Scientists	Z_{12}	Z_{13}	Z_{23}
Personal Relationships	75.0	66.7	80.0	0.68	-0.42	-1.63
TTO as a Facilitator Of Relationships Between Scientists And Firms	25.0	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 test statistics for differences in mean percentages between each class of interviewee.

** $p < .05$
* $p < .01$

Table 8
Barriers to University/Industry Technology Transfer (UITT) as Identified by Interviewees in Our Field Study

Barriers	Type of Interviewee (1) Managers/ Entrepreneurs	(2) TTO Directors/ Administrators	(3) University Scientists	Z_{12}	Z_{13}	Z_{23}
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	35.0	60.0	70.0	-1.29	-2.46*	-1.03
Bureaucracy and Inflexibility of University Administrators	80.0	6.7	70.0	3.96*	0.74	-3.51*
Insufficient Resources Devoted to Technology Transfer By Universities	35.0	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	6.7	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 test statistics for differences in mean percentages between each class of interviewee.
** $p < .05$
* $p < .01$

Table 9

Suggested Improvements to the University/Industry Technology Transfer (UITT) Process, as Identified by Interviewees in Our Field Study

Type of Interviewee

Improvements	(1) Managers/ Entrepreneurs	(2) TTO Directors/ Administrators	(3) University Scientists	Z_{12}	Z_{13}	Z_{23}
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 Formal and Informal Networking Between Scientists and Practitioners	35.0	26.7	40.0	0.65	-0.34	-1.09
Universities Need Greater Technical Expertise and Marketing Skills 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 test statistics for differences in mean percentages between each class of interviewee.

** $p < .05$

* $p < .01$