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The Effectiveness of University Technology Transfer: Lessons Learned from Quantitative and Qualitative Research in the U.S. and the U.K.

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Abstract

In recent years, there have been numerous studies of the effectiveness of university technology transfer. Such technology transfer mechanisms include licensing agreements between the university and private firms, science parks, incubators, and university-based startups. We review and synthesize these papers and present some pointed recommendations on how to enhance effectiveness. Implementation of these recommendations will depend on the mechanisms that universities choose to stress, based on their technology transfer “strategy.” For example, institutions that emphasize the entrepreneurial dimension of technology transfer must address skill deficiencies in technology transfer offices, reward systems that are inconsistent with enhanced entrepreneurial activity and the lack of training for faculty members, post-docs, and graduate students in starting new ventures or interacting with entrepreneurs. We conjecture that business schools are best positioned to address these skill and educational deficiencies through the delivery of targeted programs to technology licensing officers and members of the campus community wishing to launch startup firms.

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

Keywords: University technology transfer, entrepreneurship, technology transfer offices, science parks

I. Introduction

At the same time that technology transfer has been considered by policymakers as a driver of national and regional economic growth in the U.S. and U.K., an increasing number of university officials at leading research universities have also viewed technology transfer as a potential source of substantial revenue for their institutions. The key university technology transfer commercialization mechanisms are licensing agreements between the university and private firms, research joint ventures, and university-based startups. These activities can potentially result in financial gains for the university, other benefits to these institutions (e.g., additional sponsored research, hiring of graduate students and post-doctoral fellows), and job creation in the local region. Given the importance of these commercialization mechanisms, many universities and policymakers continually seek guidance on how to evaluate and enhance effectiveness in university technology transfer.

Organizations as the Association of University Technology Managers (AUTM) in the U.S. and the University Companies Association (UNICO) and the Association for University Research Industry Links (AURIL) in the U.K. have helped to promote technology transfer activity by publishing benchmarking surveys. These surveys have been used by scholars to explore key research questions relating to the drivers of effective university technology transfer. While these studies have been useful, the literature remains somewhat embryonic with many unresolved managerial and policy issues.

In many countries, national governments have provided support for these initiatives via legislation to facilitate technological diffusion from universities to firms (e.g., the Bayh-Dole Act of 1980) and collaborative research (e.g., the National Cooperative Research Act of 1984), subsidies for research joint ventures involving universities and firms (e.g., the European Union's

Framework Programmes and the U.S. Commerce Department's Advanced Technology Program (ATP), and shared use of expertise and laboratory facilities (e.g., the National Science Foundation's Engineering Research Centers, Science and Technology Centers, and Industry-University Cooperative Research Centers). Along these lines, national, state, and regional government authorities have also provided support for science parks and incubators.

The growth in private and public investment in university-based technology initiatives has raised important policy questions regarding the impact of such activities on researchers, universities, firms, and local regions where such investments occur. Given that many of these initiatives are relatively new, university officials and policymakers seek guidance on "best practices." More specifically, they seek evidence on specific organizational practices related to incentives, strategic objectives, and measurement and monitoring mechanisms, which might enhance technology transfer effectiveness. Inductive, qualitative research is also useful in this context, since notions of "effectiveness" are likely to vary across different types of initiatives (e.g., incubators vs. technology transfer offices) and for different players involved in such activities (e.g., university scientists, university administrators, and corporations interacting with the university).

The purpose of this paper is to review and synthesize research on the antecedents and consequences of university-based technology transfer and to explore the implications for practice and future research in this domain. Before presenting a review of the extant literature, it is useful to provide some background information on the rise of university technology transfer.

In the late 1970's, U.S. research universities were often criticized for being more adept at developing new technologies than facilitating their commercialization into the private sector (General Accounting Office, 1998). Further, it was asserted that the long lag between the

discovery and commercialization of new knowledge at the university had weakened the global competitiveness of American firms (Marshall, 1985). While such conclusions glossed over the principal mission of research universities as knowledge creators, it created enough concern for policymakers to take action. As a consequence, in 1980, the U.S. Congress attempted to remove potential obstacles to university technology transfer by passing the Bayh-Dole Act. Bayh-Dole instituted a uniform patent policy across federal agencies, 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.

In the aftermath of this legislation, almost all research universities in the U.S. established technology transfer offices (TTOs) to manage and protect their intellectual property. The number increased eightfold, to more than 200, resulting in a fourfold increase in the volume of university patents registered (Mowery & Shane, 2002). TTOs facilitate commercial knowledge transfers through the licensing to industry of patents or other forms of intellectual property resulting from university research. The Association of University Technology Managers reports that from 1991 to 1997, university revenues from licensing IP have increased over 315%, from \$220 million to \$698 million (AUTM, 2000). The number of firms that utilize university-based technologies has also increased, and evidence suggests that venture capitalists are increasingly interested in ventures founded on the basis of basic research (Small Business Association, 2002).

Our literature review will also encompass the institutional context of university technology transfer, which includes science parks, and incubators. We will also discuss the organizational context, including organizational design, processes, and incentives, as well as the

roles of individual agents, such as scientists and technology transfer officers. Finally, because much of the early research has focused measures of effectiveness and the building of robust theoretical models depended on well specified dependent variables, we review research on measures of technology transfer effectiveness such as licensing revenues, the introduction of new products and services, and new business starts.

The remainder of this article is organized as follows: In the following sections, we present an extensive review of the literature on university technology licensing, selected studies of science parks, and studies of start-up formation at universities. Section II discusses the institutional context of university technology transfer. The following section considers the organizational context of this activity. Section IV contains a discussion of the role of individual agents (i.e., academic and industry scientists, entrepreneurs, managers at firms and universities) in university technology transfer. Section V presents some methodological issues, in the context of a review of studies of licensing and business formation. Section VI presents lessons learned for policymakers and university administrators. The final section consists of conclusions.

II. The Institutional Contexts of University Technology Transfer

In Tables 1, 2, and 3, we summarize some recent quantitative and qualitative studies on university technology transfer via licensing, science parks, and new business formation, respectively. As demonstrated on these tables, recent studies concerning university technology transfer include, but are not limited to, faculty participation in technology commercialization (Bercovitz & Feldman, 2005; Owen-Smith & Powell, 2003), university licensing strategies (Feldman, Feller, Bercovitz, & Burton, 2002); university incentives and licensing revenues (Lach & Schankerman, 2005; Siegel, Waldman, & Link, 2003); U.S. and Sweden policies on invention

commercialization (Goldfarb & Henrekson, 2003); firm linkages to universities (Cohen, Nelson, & Walsh, 2002; Rothaermel & Thursby, 2005; Thursby and Thursby, 2003); issues of moral-hazard problems in technology licensing (Jensen & Thursby, 2001); the performance of licensing firms (George, Zahra, & Wood, 2002), antecedents to commercialization speed of university-based inventions (Markman, Gianiodis, Phan & Balkin, 2005a), and the performance of university-based start-up companies (Link & Scott, 2005; Lockett & Wright, 2005; Shane & Stuart, 2002). In sum, the scope and depth of the research is now at the level that we can draw normative conclusions from a review.

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It became apparent in early research that the success of a university's licensing program depended on its institutional structure, organizational capability, and incentive systems to

encourage participation by researchers. Pursuing this line of inquiry, Siegel, Waldman, and Link (2003) presented quantitative and qualitative evidence on the efficiency of university technology transfer, derived from the AUTM survey and 55 structured, in-person interviews of 100 university technology transfer stakeholders (i.e. academic and industry scientists, university technology managers, and corporate managers and entrepreneurs) at five research universities in Arizona and North Carolina. The authors concluded that intellectual property policies and organizational practices can potentially enhance (or impede) technology transfer effectiveness. Specifically, they found that informational and cultural barriers existed between universities and firms, especially for small firms, and that if these were not explicitly considered in the transfer process, the perceived attractiveness of university technology to commercial innovators is attenuated.

This result was consistent with Clarke (1998), who found evidence on the importance of institutional norms, standards, and culture. Based on a qualitative analysis of five European universities that had outstanding performance in technology transfer, he concluded that the existence of an entrepreneurial culture at those institutions was a critical factor in their success (Clarke, 1998). Additionally, Roberts (1991) found that social norms and MIT's tacit approval of entrepreneurs were critical determinants of successful academic entrepreneurship at MIT.

Interestingly, the availability of venture capital in the region where the university is located and the commercial orientation of the university (proxied by the percentage of the university's research budget that is derived from industry) are found to have an insignificant impact on the rate of startup formation (DiGregorio and Shane, 2003).

Degroof and Roberts (2004) examine the importance of university policies related to startups in regions where environmental factors (e.g., technology transfer and infrastructure for entrepreneurship) are not particularly conducive to entrepreneurial activity. The authors offered taxonomy for four types of startup policies: an absence of startup policies, minimal selectivity/support, intermediate selectivity/support, and comprehensive selectivity/support. Consistent with Roberts and Malone (1996), they found that comprehensive selectivity/support is the optimal policy for generating startups that can exploit venture with high growth potential. However, while such a policy is ideal, it may not be feasible given the resource constraints faced by universities. The authors conclude that while spinout policies matter in the sense that they affect the growth potential of ventures, it may be more desirable to formulate such policies at a higher level of aggregation than the university.

Franklin, Wright, and Lockett (2001) analyze perceptions at U.K. universities regarding entrepreneurial startups that emerge from university technology transfer. The authors distinguish between academic and surrogate (external) entrepreneurs and “old” and “new” universities in the U.K. Old universities have well-established research reputations, world-class scientists, and are typically receptive to entrepreneurial startups. New universities, on the other hand, tend to be somewhat weaker in academic research and less flexible with regard to entrepreneurial ventures. They find that the most significant barriers to the adoption of entrepreneurial-friendly policies are cultural and informational and that the universities generating the most startups (i.e., old universities) are those that have the most favorable policies regarding surrogate (external) entrepreneurs.

III. The Organizational Context of University Technology Transfer

Bercovitz, Feldman, Feller, and Burton (2001) examine the *organizational structure* of the TTO and its relationship to the overall university research administration. Based on the theoretical work of Alfred Chandler and Oliver Williamson, they analyze the performance implications of four organizational forms: the functional or unitary form (U-Form), the multidivisional (M-form), the holding company (H-form), and the matrix form (MX-form). The authors note that these structures have different implications for the ability of a university to coordinate activity, facilitate internal and external information flows, and align incentives in a manner that is consistent with its strategic goals with respect to technology transfer.

To test these assertions, they examine TTOs at Duke, Johns Hopkins, and Penn State and find evidence of alternative organizational forms at these three institutions. They attempt to link these differences in structure to variation in technology transfer performance along three dimensions: transaction output, the ability to coordinate licensing and sponsored research activities, and incentive alignment capability. While further research is needed to make conclusive statements regarding organizational structure and performance, their findings imply that organizational form does matter.

Related to this issue of organizational structure, a surprising conclusion of Markman, Phan, Balkin, and Giannodis (2005) is that the most “attractive” combinations of technology stage and licensing strategy for new venture creation, i.e. early stage technology, combined with licensing for equity, are least likely to be favored by the university and thus not likely to be used. That is because universities and TTOs are typically focused on short-term cash maximization, and extremely risk-averse with respect to financial and legal risks. Their findings are consistent with evidence presented in Siegel, Waldman, Atwater, and Link (2004), who found that TTOs

appear to do a better job of serving the needs of large firms than small, entrepreneurial companies. The results of these studies imply that universities should modify their technology transfer strategies if they are serious about promoting entrepreneurial development. In Markman, Phan, Balkin, and Giannodis (2005b), the authors find that speed of process matters, in the sense that the “faster” TTOs can commercialize technologies that are protected by patents, the greater the returns to the university and the higher the rate of startup formation. They also report that there are three key determinants of speed: TTO resources, competency in identifying licensees, and participation of faculty-inventors in the licensing process.

Along the same lines of inquiry, Lockett and Wright (2005) assessed the relationship between the resources and capabilities of U.K. TTOs and the rate of startup formation at their respective universities. Here, the authors apply the resource-based view (RBV) of the firm to the university. RBV asserts that an organization’s superior performance (in the parlance of strategic management, its “competitive advantage”) is related to its internal resources and capabilities. They are able to distinguish empirically between a university’s resource inputs and its routines and capabilities.

Based on estimation of count regressions (Poisson and Negative Binomial), the authors conclude that there is a positive correlation between startup formation and the university’s expenditure on intellectual property protection, the business development capabilities of TTOs, and the extent to which its royalty distribution formula favors faculty members. These findings imply that universities wishing to spawn numerous startups should devote greater attention to recruitment, training, and development of technology transfer officers with broad-based commercial skills.

Markman, Gianiodis and Phan (2006), using a statistically random sample of 54 U.S. universities and 23,394 faculty/scientists, showed that bypassing (or gray market) activity is reduced when universities professionalize their technology licensing offices and when monitoring is delegated to dual agents who can better monitor agents, namely scientists/faculty departments. Interestingly, the study also shows that increased bypassing activity is associated with more valuable discoveries and heightened entrepreneurial activities, highlighting the conundrum found in other studies; that universities focused on entrepreneurial startups may do well to reduce restrictions over intellectual property flows!

Siegel, Waldman, and Link (2003) found that the high rate of turnover among licensing officers was detrimental towards the establishment of long-term relationships with firms and entrepreneurs. Other concerns they found were insufficient business and marketing experience in the TTO and the possible need for incentive compensation, as indicated by other studies. In a subsequent paper, Link and Siegel (2005) find that the “royalty distribution formula,” which determines the fraction of revenue from a licensing transaction that is allocated to a faculty member who develops the new technology can potentially enhance technology licensing (as distinct from startup formation).

Using data on 113 U.S. TTOs, the authors found that universities allocating a higher percentage of royalty payments to faculty members tend to be more efficient in technology transfer activities (closer to the production frontier). Organizational incentives for university technology transfer therefore appear to be an important determinant of success. This finding was independently confirmed in Friedman and Silberman (2003) and Lach and Schankerman (2004), using slightly different methods and data. Finally, Markman, Gianiodis and Phan (2006) found

that increasing royalty revenues to scientists' departments is associated with increased gray market activity and patent citations.

According to Thursby & Thursby (2004), TTOs can be modeled dual agents to obtain discoveries from faculty and to manage the commercialization process to industry incumbents for the university. TTOs assess the potential rents derived from discoveries; seek IP protection for promising discoveries; solicit research sponsors and potential technology licensees; and manage and enforce contractual agreements with partners and licensees (cf., Markman, et al. 2005c). Hence, the structure of the TTO, as Markman, Phan, Balkin, and Giannodis (2004) found, was critical to the success of the transfer process.

Using an agency theoretic approach, Jensen, Thursby, and Thursby (2003) modeled the process of faculty disclosure and university licensing through a TTO as a game, in which the principal is the university administration and the faculty and TTO is a dual agent who maximized expected utilities. The game is played when faculty members decide whether to disclose the invention to the TTO and at what stage, i.e. whether to disclose at the most embryonic stage or wait until it is a lab-scale prototype. If an invention is disclosed, the TTO decides whether to search for a firm to license the technology and then negotiates the terms of the licensing agreement with the licensee. The university administration influences the incentives of the TTO and faculty members by establishing policies for the distribution of licensing income and/or sponsored research. According to the authors, the TTO engaged in a "balancing act," in the sense that it can influence the rate of invention disclosures, must evaluate the inventions once they are disclosed, and negotiate licensing agreements with firms as the agent of the administration.

The Jensen, Thursby, and Thursby (2003) theoretical analysis generates some interesting empirical predictions. For instance, in equilibrium, the probability that a university scientist discloses an invention and the stage at which he or she discloses the invention is related to the pecuniary reward from licensing, as well as faculty quality. The authors test the empirical implications of the dual agency model based on an extensive survey of the objectives, characteristics, and outcomes of licensing activity at 62 U.S. universities.¹ Their survey results provide empirical support for the hypothesis that the TTO is a dual agent. They also find that faculty quality is positively associated with the rate of invention disclosure at the earliest stage and negatively associated with the share of licensing income allocated to inventors.

Related to the above issue, Siegel, Waldman, and Link (2003) identified a mismatch between incentive systems for faculty involvement and the commercialization goals for university technology transfer. This includes both pecuniary and non-pecuniary rewards, such as credit towards tenure and promotion. Some respondents in the study even suggested that involvement in technology transfer could be detrimental to their careers. Other authors have explored the role of incentives in university technology transfer. For example, Markman, Phan, Balkin, and Giannodis (2004, 2005a) assessed the role of incentive systems in stimulating academic entrepreneurship and the determinants of innovation speed, or time to market. An interesting result of Markman, Phan, Balkin, and Giannodis (2004) is that there is a positive association between compensation to TTO personnel and both equity licensing and startup formation. Paradoxically, DiGregorio and Shane (2003) found that a royalty distribution formula that is more favorable to faculty members reduced startup formation, a finding that is confirmed by Markman, Phan, Balkin & Giannodis (2005a). DiGregorio and Shane (2003) attributed this

¹ See Thursby, Jensen, and Thursby (2001) for an extensive description of this survey.

result to the higher opportunity cost associated with launching a new firm, relative to licensing the technology to an existing firm.

O'Shea, Allen, and Arnaud (2005) extend these findings in several ways. First, they employ a more sophisticated econometric technique employed by Blundell, Griffith, and Van Reenen (1995) on innovation counts, which accounts for unobserved heterogeneity across universities due to "history and tradition." This type of "path dependence" would seem to be quite important in the university context since university policies tend to evolve slowly. Indeed, the authors find that a university's previous success in technology transfer is a key explanatory factor of startup formation. Consistent with DiGregorio and Shane (2003), they also find that faculty quality, commercial capability, and the extent of federal science and engineering funding are also significant determinants of higher rates of university startup formation.

Moray and Clarysse (2005) adopt an institutional perspective on spinning off ventures as a venue for commercializing research. The central question they consider is the following: Are the resource endowments of science-based entrepreneurial firms at time of founding influenced by the way in which technology transfer is organized by the parent? Interestingly, they adopt a multi-level longitudinal data approach and a mix of quantitative qualitative techniques based on the Inter University Micro Electronics Centre (henceforth, IMEC) in Belgium, a research institute known for its international research excellence and with a track record in spinning off ventures. Using archival data sources, standardized questionnaires and semi-structured interviews, they collect regional data on spin out activity, data about technology transfer policies from all (senior) managers involved and data about the 23 science-based entrepreneurial ventures that emerged from the institute until 200. The authors assert that changes in the internal

institutional set up -- and the technology transfer policy in particular – go together with a changing overall tendency in the resources endowed to the science-based entrepreneurial firms.

They identified three generations of companies displaying the main organizational changes in technology transfer policies and showed distinct resource characteristics at time of founding. The first generation of companies established during 1986-1995, received insufficient funding and the lack of experience of IMEC meant led to difficulties in evaluating capital needs. Most of the companies had a working alpha prototype when they started their business activities but these did not involve the formal transfer of technology from the university. During the second generation from 1996 to 1998, IMEC increasingly began to bring in IP into the firms through licensing agreements but failed to do so in a systematic way. Some of the firms established in this period involved the spinning-off of technology and the receipt of start capital from IMEC and the attraction of further capital after 12-18 months from seed capital funds, business angels and venture capitalists once the workability of an alpha prototype had been demonstrated.

The third generation starters in the period 1999-2002 were characterized by almost all being spin-offs and with a less mature technology, reflecting the increasing technology push model adopted by IMEC. During this period, IP was brought into the spin-off in exchange for equity. IMEC researchers involved in the research project were more likely to join the company, instead of remaining an employee at IMEC. The mean initial capital increased significantly during this period although IMEC did not invest cash in its spin-offs at time of founding.

Moray and Clarysse's paper builds on existing research that demonstrates that PRIs may undertake different generic approaches to spinning-out new ventures, i.e., low selective, supportive and incubator (Clarysse, Wright, Lockett, A., van de Elde and Vohora, 2005). IMEC

is an interesting case where the PRI, in effect, became an incubator over time; the third phase outlined by Moray and Clarysse. Their research shows that the strategy of the PRI to become an incubator has an effect on the type of new ventures being created.

Powers and McDougall (2005) test a model of a PRI's selectivity and support policy orientation for technology licensing and its interaction with the external environment for entrepreneurship. Utilizing previous research on technology transfer practice, combined with contingency theory, they investigate the direct and interactive effects among a university's policy orientation and a new composite measure of the external entrepreneurial environment in which a university is embedded, entrepreneurial density, on downstream performance. The authors measure performance as the number of licensee firms that subsequently go public and product sale royalties. Based on AUTM data from 134 U.S. research universities, data from IPO listing prospectuses, and additional private and governmental data sources, they estimate hierarchical moderated regression main, two-way and three-way interaction effects for two measures of technology transfer performance - licenses with companies that subsequently go public and product royalties.

The authors find that both selectivity and entrepreneurial density are significant positive predictors of the number of licenses held with private companies that subsequently went public. However, a university's selectivity and support orientation was not found to be significantly influenced by the density or sparseness of the external entrepreneurial environment. Further, university technology transfer performance measured in terms of IPO firms did not appear to depend on the policy orientation, nor is that policy orientation significantly influenced by the external environment for entrepreneurship. With respect to product royalties, they find that universities that are more selective about their choices for what to patent and license via the start-

up and small company route appear to be especially disadvantaged in terms of royalty flows when they provide a high degree of support for their technology transfer program. Conversely, universities that are less selective appear to be advantaged by a stronger support orientation. For those universities in the middle third of the support range, an increase in selectivity results in a decreasing royalty benefit up to a point. The same benefits were not evident for those universities that pursue either a high selectivity *and* high support policy orientation or a low support *and* low selectivity policy orientation.

Lockett and Wright (2005), utilizing data from a U.K. survey of all research universities that are active in spinning-out ventures and adopting count data analysis, while controlling for the presence of a medical school and regional R&D expenditure, address a key omission in the literature concerning the role of the resources and capabilities of universities and their TTO. The presence of sufficient experience and expertise within what are historically non-commercial environments may be central to their ability to generate gains from spin-out ventures. The authors assert that it is important to distinguish between the roles of the stock of universities' resource inputs and their routines/capabilities in affecting the creation of spin-out companies.

The authors report that both the number of spin-out companies created and the number of spin-out companies created with equity investment are significantly positively associated with expenditure on intellectual property protection, the business development capabilities of technology transfer offices and the royalty regime of the university. In contrast, they do not find that the number of start-ups is associated significantly with the number of TTO staff, the years the TTO has been in existence of the available technology.

Markman, Gianiodis, and Phan (2005), using interview data from 91 university TTOs in the U.S., supplemented by archival data on commercialization activity and university

characteristics from other sources, assess the determinants of time to market in academic entrepreneurship. Employing path analysis, incorporating hierarchical regressions, they find that the shorter the time to market, the greater the returns to the university and the higher the rate of startup formation. They find that during the discovery and disclosure stage, TTO's resources—lack of time, capital, or poor central administration support for licensing activity—are less of a hindrance to speedy commercialization than the limitations posed by inventor-related impediments such as resistance, indifference, and poor-quality disclosures. However, during advanced commercialization stages, faculty-inventors seem to play a more positive role in accelerating the process. It could be that some faculty-inventors are the founders of these technology-based startups, which means that their interest in the new venture extends beyond the licensing process, involving the management of the commercialization process itself.

Rothaermel and Thursby (2005) consider the importance for incubator firms of linkages to universities. They focus on two types of university linkages: a license obtained from the university by the incubator firm and their links to faculty. The authors propose that a university link to the sponsoring institution reduces the probability of new venture failure and, at the same time, retards timely graduation. Furthermore, they suggest that these effects are more pronounced the stronger the university-incubator link.

Their empirical analysis is based on detailed longitudinal data from 79 start-up firms incubated in the Advanced Technology Development Center at the Georgia Institute of Technology over the six-year period between 1998 and 2003. They estimate multinomial logistic regressions, using maximum likelihood methods, to assess the determinants of three alternatives for these ventures: failure, remaining on the incubator, or successful graduation.

The authors find that a new venture's university linkages through a Georgia Tech license and/or through having a Georgia Tech professor on the firm's management senior team significantly reduce the new venture's chances of outright failure, but also significantly retard the firm's graduation from the incubator. They attribute the probability of reduced new venture failure to the venture being founded on a technology licensed from the university sponsoring the incubator, while retarded graduation stems from links to faculty from the incubator-sponsoring university. The authors also report that only strong ties matter when predicting graduation within three years or less.

Ensley and Hmieleski (2005) analyze differences between firms that are spun out from university-affiliated business incubators and technology parks and those who emerge without such assistance. The authors draw on institutional isomorphism theory to predict that university-affiliated new venture top management teams (henceforth, TMTs) will be more homogenous in composition, display less developed team dynamics, and as a result, be lower performing than those without university affiliation. They adopt the view that university-affiliated firms will institutionalize themselves toward the norms of the university and the successful ventures that have been launched through their nurturing, rather than toward their own industry, what they term "localized" isomorphic behavior. The costs associated with localized isomorphism are used to explain why the benefits of university affiliation might fail to translate into performance gains.

They test for differences in TMT composition (education, functional expertise, industry experience, and skill), dynamics (shared strategic cognition, potency, cohesion, and conflict) and performance (net cash flow and revenue growth) between a sample of 102 high-technology startups that are affiliated with university incubators and technology parks and an observationally-equivalent sample of 154 ventures that are unaffiliated with such facilities. Using discriminant

analysis and multiple regression, they find university-affiliated start-ups to be comprised of more homogenous TMTs with less developed dynamics than their unaffiliated counterparts. Furthermore, university-affiliated start-ups are found to have significantly lower performance, in terms of net cash flow and revenue growth, than unaffiliated new ventures.

The issue of geographic location is highlighted in two key papers. First, Link and Scott (2005) analyze the determinants of the new venture formation within university science parks (a property-based incubator). They focus on science parks because these institutions are designed to enhance knowledge spillovers between universities and tenant firms, and to enhance regional economic growth. Adopting an institutional environment perspective, they conjecture that there are two critical factors that explain the rate of spin-off formation: the research environment of the university and the characteristics of the research park to which the spin-off companies locate.

The authors conjecture that the more research intensive the university, the greater the probability that faculty will innovate; and, the more innovative the faculty, the greater the probability that technologies will develop around which a spin-off company could be based. They also hypothesize that the formation of university spin-off companies into the university's park will occur more often in older parks than in newer ones as these have developed the expertise to facilitate opportunity recognition and development. To test these hypotheses, the authors collected survey data for 51 U.S. research parks, which they supplemented with interviews of provosts at these institutions. The dependent variable in their analysis is the percentage of firms on the park that are university spin-offs. The authors employ Tobit estimation and control for university and park characteristics. The empirical results indicate that university spin-off companies are a greater proportion of the companies in older parks and in parks that are associated with richer university research environments. They also find that

university spin-off companies are a larger proportion of companies in parks that are geographically closer to their university and in parks that have a biotechnology focus.

The importance of location is also examined in Audretsch, Lehmann and Warning (2005), who assess the role of a firm's choice of location as a firm strategy to exploit knowledge spillovers from universities. The authors hypothesize that proximity to the university is shaped by different spillover mechanisms -- research and human capital -- and by different types of knowledge spillovers -- natural sciences and social sciences. Their primary source of data consists of 281 young high-technology start-ups that are publicly listed on the Neuer Markt in Germany between 1997 and 2002. Data are also drawn from multiple archival sources, including listing prospectuses relating to the firms and government and other sources relating to university data.

Based on OLS regressions, their results suggest that spillover mechanisms as well as spillover types are heterogeneous. More importantly, the authors find that firm spin-offs, at least in the knowledge and high technology sectors, are influenced not only by the traditional regional and economic characteristics, but also by the opportunity to access knowledge generated by universities. However, the exact role that geographic proximity plays is shaped by the two factors examined in this paper - the particular knowledge context, and the specific type of spillover mechanism.

In sum, contrary to conventional economic models researchers have found that the variation in relative TTO performance cannot be completely explained by environmental and institutional factors. Instead, the extant literature on TTOs suggests that the key impediments to effective university technology transfer tend to be organizational in nature (Siegel, Waldman, and Link, 2003, Siegel, Waldman, Atwater, and Link, 2003). These include problems with

differences in organizational cultures between universities and (small) firms, incentive structures, including both pecuniary and non-pecuniary rewards, such as credit towards tenure and promotion, and staffing and compensation practices of the TTO itself.

IV. The Individual Contexts of University Technology Transfer

Taking the analysis a level deeper, several studies have focused on individual scientists and entrepreneurs in the context of university technology transfer. Audretsch (2000) examines the extent to which entrepreneurs at universities are different than other entrepreneurs. He analyzes a dataset on university life scientists in order to estimate the determinants of the probability that they will establish a new biotechnology firm. Based on a hazard function analysis, including controls for the quality of the scientist's research, measures of regional activity in biotechnology, and a dummy for the career trajectory of the scientist, the author finds that university entrepreneurs tend to be older and more scientifically experienced.

The seminal papers by Lynne Zucker and Michael Darby and various collaborators explore the role of "star" scientists in the life sciences on the creation and location of new biotechnology firms in the U.S. and Japan. In Zucker, Darby and Armstrong (2000), the authors assessed the impact of these university scientists on the research productivity of U.S. firms. Some of these scientists resigned from the university to establish a new firm or kept their faculty position, but worked very closely with industry scientists. A star scientist is defined as a researcher who has discovered over 40 genetic sequences, and affiliations with firms are defined through co-authoring between the star scientist and industry scientists. Research productivity is measured using three proxies: number of patents granted, number of products in development, and number of products on the market. They find that ties between star scientists and firm

scientists have a positive effect on these three dimensions of research productivity, as well as other aspects of firm performance and rates of entry in the U.S. biotechnology industry (Zucker, Darby, and Armstrong, 1998; Zucker, Darby, and Brewer, 1998).

In Zucker and Darby (2001), the authors examine detailed data on the outcomes of collaborations between “star” university scientists and biotechnology firms in Japan. Similar patterns emerge in the sense that they find that such interactions substantially enhance the research productivity of Japanese firms, as measured by the rate of firm patenting, product innovation, and market introductions of new products. However, they also report an absence of geographically localized knowledge spillovers resulting from university technology transfer in Japan, in contrast to the U.S., where they found that such effects were strong. The authors attribute this result to the following interesting institutional difference between Japan and the U.S. in university technology transfer. In the U.S., it is common for academic scientists to work with firm scientists at the firm’s laboratories. In Japan, firm scientists typically work in the academic scientist’s laboratory. Thus, according to the authors, it is not surprising that the local economic development impact of university technology transfer appears to be lower in Japan than in the U.S.

Louis, Blumenthal, Gluck, and Stoto (1989) analyze the propensity of life-science faculty to engage in various aspects of technology transfer, including commercialization. Their statistical sample consists of life scientists at the 50 research universities that received the most funding from the National Institutes of Health. The authors find that the most important determinant of involvement in technology commercialization was local group norms. They report that university policies and structures had little effect on this activity.

The unit of analysis in Bercovitz and Feldman (2004) was also the individual faculty member. They analyze the propensity of medical school researchers at Johns Hopkins and Duke to file invention disclosures, a potential precursor to technology commercialization. The authors find that three factors influence the decision to disclose inventions: norms at the institutions where the researchers were trained and the disclosure behaviors of their department chairs and peers, respectively. Related to this research, Roberts and Malone (1996), using the example of Stanford in the early 1990s, conjecture that technology transfer stimulated entrepreneurial activity was a function of university policies (Stanford refused to grant exclusive licenses to inventor-founders). DiGregorio and Shane (2003) directly assess the determinants of startup formation using AUTM data from 101 universities and 530 startups. Based on estimates of count regressions of the number of university-based startups, they conclude that the two key determinants of startups are faculty quality and the ability of the university and inventor(s) to assume equity in a start-up in lieu of licensing royalty fees.

In sum, to the extent that the successful commercialization of university technology depends on the individual incentives, risk taking propensities, and skill sets of academic entrepreneurs, the research seems to suggest that paying attention to the individual level of analysis matters in building more complete models of technology transfer effectiveness. Specifically, the ability for academics to identify commercial opportunities is driven by their technical expertise, experience in past commercialization attempts, and their personal networks outside the university context. Their willingness to engage in such activities is primarily related to the incentives they are offered and/or the perceived risk/return outcomes.

V. Measuring the Effectiveness of University Technology Transfer (Licensing and Business Formation)

A useful way to assess and explain the effectiveness of university technology transfer is to model this within a production function/frontier framework. Such a production function is typically estimated econometrically. Production frontiers are also estimated using nonparametric models, which offer some advantages, relative to the parametric approach. For instance, these methods obviate the need to specify a functional form for the production frontier and also enable us to identify “best practice” universities. Nonparametric techniques can also handle multiple outputs.

Perhaps the most popular non-parametric estimation technique is data envelopment analysis (DEA). The DEA method is essentially a linear-program, which can be expressed as follows:

$$(1) \quad \text{Max } h_k = \frac{\sum_{r=1}^s u_{rk} Y_{rk}}{\sum_{i=1}^m v_{ik} X_{ik}}$$

subject to

$$(2) \quad \frac{\sum_{r=1}^s u_{rk} Y_{rj}}{\sum_{i=1}^m v_{ik} X_{ij}} < 1; j=1, \dots, n$$

$$\text{All } u_{rk} > 0; v_{ik} > 0$$

where

Y = a vector of outputs

X = a vector of inputs

i = inputs (m inputs)

r = outputs (s outputs)

n = # of decision-making units (DMUs), or the unit of observation in a DEA study

The unit of observation in a DEA study is referred to as the decision-making unit (DMU). A maintained assumption of this class of models is that DMUs attempt to maximize efficiency. Input-oriented DEA yields an efficiency “score,” bounded between 0 and 1, for each DMU by choosing weights (u_r and v_i) that maximize the ratio of a linear combination of the unit's outputs to a linear combination of its inputs (see equation (2)). These scores are often expressed as percentages. A DMU having a score of 1 is efficient, while those with scores of less than one are (relatively) inefficient. Multiple DMUs have scores of 1.

DEA fits a piecewise linear surface to rest on top of the observations. This is referred to as the "efficient frontier." The efficiency of each DMU is measured relative to all other DMUs, with the constraint that all DMU's lie on or below the efficient frontier. The linear programming technique identifies best practice DMUs, or those that are on the frontier. All other DMUs are viewed as being inefficient relative to the frontier DMUs.

Stochastic frontier estimation (SFE) is a parametric method 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. Following Battese and Coelli (1995), the stochastic frontier model in cross sectional form is:

$$(3) Y_i = \exp(x_i\beta + V_i - U_i)$$

where Y_i represents the output or production of the i -th observation ($i=1,2,\dots,N$); x_i is a $(1 \times k)$ vector of values of inputs or resources used in production; and i denotes the i -th firm. β is a $(k \times$

1) vector of unknown parameters to be estimated. The V_i s are assumed to be iid $N(0, \sigma_v^2)$ random errors, distributed independently of the U_i s. The U_i s are the non-negative random variables associated with technical inefficiency of production, which are assumed to be independently distributed, such that U_i is obtained by truncation (at zero) of the normal distribution with a mean $z_i\delta$ and a variance, σ^2 . Z_i is a $(1 \times m)$ vector of explanatory variables associated with technical inefficiency of the production of observations and finally δ is an $(1 \times m)$ vector of unknown coefficients.

Equation (3) specifies the stochastic frontier production function in terms of the original production values. In order to explain technical efficiency, this model needs to be extended to make technical efficiency conditional on exogenous variables. Following Battese and Coelli (1995), we can model explanatory variables in a one stage SFE model. That is, the technical inefficiency effects, the U_i s, are assumed to be a function of a set of explanatory variables, the z_i s and the unknown vector of coefficients δ . If all the elements of the δ vector are equal to 0, then the technical inefficiency effects are not related to the z variables, and so the half normal distribution specified in Aigner, Lovell and Schmidt (1977) is obtained.

The technical inefficiency effect, U_{it} , in the stochastic frontier model (3) can be specified as:

$$(4) U_i = z_i\delta + W_i$$

where the random variable, W_i is defined by the truncation of the normal distribution with zero mean and variance, σ^2 .

The method of maximum likelihood is used for the simultaneous estimation of the parameters of the stochastic frontier model and the model for the technical inefficiency effects. The likelihood function is expressed in terms of the variance parameters, $\sigma_s^2 \equiv \sigma_v^2 + \sigma_u^2$ and $\gamma \equiv \sigma_u^2 / \sigma_s^2$. Therefore γ is the ratio of the standard error of technical inefficiency to the standard error of statistical noise, and is bounded between 0 and 1. Note that $\gamma = 0$ under the null hypothesis of an absence of inefficiency, indicating that all of the variance can be attributed to statistical noise. The technical efficiency of production for the i -th observation is defined by:

$$(5) TE_i = \exp(-U_i) = \exp(-z_i\delta - W_i)$$

Choosing between the parametric stochastic frontier estimation (SFE) and the non-parametric data envelopment analysis (DEA) is not without controversy (Gong and Sickles, 1993). A main attraction of stochastic frontier analysis is that it allows hypothesis testing and construction of confidence intervals. A drawback of the approach, however, is the need to assume a functional form for the production function and for the distribution of the technical efficiency term. The use of DEA obviates the need to make these assumptions and, as noted earlier, also allows for multiple outputs in the production function. However, a major weakness of DEA is that it is deterministic. Hence, DEA does not distinguish between technical inefficiency and noise.

Chapple, Lockett, Siegel, and Wright (2006) assert that the technology transfer is characterized by multiple outputs: licensing and start-up activity. With multiple outputs, it is appropriate to employ a “distance” function approach, which can be considered as a generalization of the single output production (or cost) frontier. Distance functions can be estimated using non-parametric or parametric methods. A simple parametric distance function can be expressed as:

$$\ln D_o = \alpha_0 + \sum_{m=1}^{M-1} \alpha_m \ln y_m + \sum_{k=1}^K \ln x_k + \ln \varepsilon \quad (6)$$

Noting that homogeneity implies that:

$$D_o(x, \omega y) = \omega D_o(x, y) \quad (7)$$

Hence, if we arbitrarily choose one of the outputs, such as the Mth output, and set $\omega=1/Y_M$, we obtain:

$$D_o(x, y / y_M) = D_o(x, y) / y_M \quad (8)$$

For the Cobb Douglas case, this yields:

$$\ln(D_{O/y_M}) = \alpha_0 + \sum_{m=1}^{M-1} \alpha_m \ln y^* + \sum_{K=1}^k \beta_K \ln x_k + \ln \varepsilon \quad (9)$$

where $y^* = y_m / y_M$

and the distance function can be expressed more concisely as:

$$-\ln(D_o) - \ln(y_M) = CD(x, y / y_M, \alpha, \beta) \quad (10)$$

and hence:

$$-\ln(y_M) = CD(x, y / y_M, \alpha, \beta) + \ln(D_o) \quad (11)$$

Thus, if we append a symmetric error term, v to account for statistical noise and re-write $\ln(D_o)$ as μ , we can obtain the stochastic output distance function, with the usual composite error term ε

$=v+\mu$. We make the standard assumptions that the v are normally distributed random variables while the μ are assumed to have a truncated normal distribution:

$$-\ln(y_M) = CD(x, y / y_M, \alpha, \beta) + v - \mu \quad (12)$$

As in the stochastic frontier approach, the predicted value of the output distance function for the i^{th} firm, $D_{oi} = \exp(-\mu)$ is not directly observable but must be derived from the composed error term, ε_i . Therefore, predictions for D_o are obtained using Coelli's Frontier 4.1 program, based on the conditional expectation $D_{oi} = E[(-\mu) \varepsilon_i]$.

We now turn to some specific productivity studies. Referring to Table 1, we note that effectiveness usually refers to a measure of "productivity," which are constructed from indicators of "outputs" and "inputs" of university technology transfer (e.g., Siegel, Waldman, and Link, 2003; Thursby and Thursby, 2002; Friedman and Silberman, 2003; and Chapple, Lockett, Siegel, and Wright, 2005). Some of these productivity studies are based on non-parametric methods, such as data envelopment analysis (henceforth, DEA), a linear programming method. Others employ parametric estimation procedures, such as stochastic frontier estimation (henceforth, SFE).

Siegel, Waldman, and Link (2003) employ SFE to assess and "explain" the relative productivity of 113 U.S. university TTOs. In their model, licensing activity is treated as the output and invention disclosures, full-time equivalent employees in the TTO, and legal expenditures are considered to be inputs. They find that the production function model yields a good fit. Based on estimates of their "marginal product," it appears that technology licensing officers add significant value to the commercialization process. The findings also imply that

spending more on lawyers reduces the number of licensing agreements but increases licensing revenue. Licensing revenue is subject to increasing returns, while licensing agreements are characterized by constant returns to scale. An implication of increasing returns for licensing revenue is that a university wishing to maximize revenue should spend more on lawyers.

Perhaps this would enable university licensing officers to devote more time to eliciting additional invention disclosures and less time to negotiating with firms.

While licensing has traditionally been the most popular mechanism for commercialization of university-based technologies, universities are increasingly emphasizing the entrepreneurial dimension of technology transfer (see Table 2). The Association of University Technology Managers (AUTM, 2004) reports that the number of startup firms at U.S. universities rose from 35 in 1980 to 374 in 2003. This rapid increase in startup activity has attracted considerable attention in the academic literature. Some researchers have focused on the university as the unit of analysis, while others analyze entrepreneurial agents (either academic or non-academic entrepreneurs).

Franklin, Wright, and Lockett (2001) conclude that the best approach for universities that wish to launch successful technology transfer startups is a combination of academic and surrogate entrepreneurship. This would enable universities to simultaneously exploit the technical benefits of inventor involvement and the commercial know-how of surrogate entrepreneurs. In a subsequent paper, Lockett, Wright and Franklin (2003) find that universities that generate the most startups have clear, well-defined strategies regarding the formation and management of spinouts. These schools tend to use surrogate (external) entrepreneurs, rather than academic entrepreneurs, to manage this process. It also appears as though the more successful universities have greater expertise and vast social networks that help them generate

more startups. However, the role of the academic inventor was not found to differ between the more and less successful universities. Finally, equity ownership was found to be more widely distributed among the members of the spinout company in the case of the more successful universities.

Markman, Phan, Balkin, and Giannodis (2005) develop a model linking university patents to new-firm creation in university-based incubators, with university TTOs acting as the intermediaries. While there have been some qualitative studies of university originated new business formation (e.g. Bercovitz Feldman, Feller, and Burton, 2001; Siegel, Waldman, and Link, 2003; Mowery, Nelson, Sampat, and Ziedonis, 2001), they have been based on data from elite research universities only (e.g. Stanford, UC Berkeley, and MIT) or from a small sample of more representative institutions. To build a theoretically saturated model of TTOs' entrepreneurial development strategies, the authors collected qualitative and quantitative data from virtually the entire population of university TTOs. In a subsequent paper, Markman, Gianiodis and Phan (2006) found that entrepreneurial activity was positively correlated to gray market activities, which raises a conundrum for university administrators interested in pursuing greater level of entrepreneurial intensity.

Nerkar and Shane (2003) analyze the entrepreneurial dimension of university technology transfer, based on an empirical analysis of 128 firms that were founded between 1980 and 1996 to commercialize inventions owned by MIT. They begin by noting that there is an extensive literature in management that suggests that new technology firms are more likely to survive if they exploit radical technologies (e.g. Tushman and Anderson, 1986) and if they possess patents with a broad scope (e.g., Merges and Nelson, 1990). The authors conjecture that the relationships between radicalness and survival and scope and survival are moderated both by the

market structure or level of concentration in the firm's industry. Specifically, they assert that radicalness and patent scope increase the probability of survival more in fragmented industries than in concentrated sectors. They estimate a hazard function model using the MIT database and find empirical support for these hypotheses. Thus, the effectiveness of the technology strategies of new firms may be dependent on industry conditions.

Technology incubators are university-based technology initiatives that are designed to facilitate knowledge transfer from the university to firms located on such facilities. Rothaermel and Thursby (2005) investigate the research question of how knowledge actually flows from universities to incubator firms. The authors assess the effect of these knowledge flows on incubator firm-level differential performance. Based on the resource-based view of the firm and the absorptive capacity construct, they hypothesize that knowledge flows should enhance incubator firm performance. Drawing on detailed, longitudinal firm-level data on 79 technology ventures incubated between 1998 and 2003 at the Advanced Technology Development Center, a technology incubator sponsored by the Georgia Institute of Technology, the authors find some support for knowledge flows from universities to incubator firms. Their evidence suggests that incubator firms' absorptive capacity is an important factor when transforming university knowledge into firm-level competitive advantage.

The transfer of scientific and technological know-how into valuable economic activity has become a high priority for many nations and regions. The emphasis on the role and the nature of "industry science links" during this transfer process is an important dimension of this emerging policy orientation. Debackere and Veugelers (2005) explore the diverse and evolutionary nature of industry science links, as well as the major motivations driving them. The

establishment of technology transfer offices can be seen as providing both a strategic and a structural response towards embedding industry science links within academic institutions.

The authors explore the case of K.U. Leuven R&D, the technology transfer organization affiliated with K.U. Leuven in Belgium, as well as a comparison group of 11 European research universities. They identify numerous factors influencing the management of technology transfer relationships. Consistent with evidence from the U.S. (see Link and Siegel (2005)), they find that incentives and organization practices are important, in terms of explaining variation in relative performance. Specifically, they report that universities allocating a higher percentage of royalty payments to faculty members tend to be more effective in technology transfer. On the organizational side, the authors find that another critical success factor is what they call a “decentralized management style,” which apparently allows the technology transfer office to be much more sensitive to the needs of its stakeholders.

Audretsch and Lehmann (2005) examine the success of technical universities in facilitating the spillover and commercialization of knowledge by firms. The authors compare the impact of technical and general universities on the performance of knowledge-based firms. Technical universities are expected to have a stronger impact than general universities in stimulating such spillovers. These institutions, which were established in Germany in the mid-nineteenth century, focus on science engineering. They have received more research grants and state funding, compared to general universities.

The authors test the hypothesis of differential impact based on a unique data set, consisting of publicly-held high technology firms in Germany. Interestingly, the authors report that firm performance is not influenced by the type of university it interacts with. That is,

technical universities do not have a differential impact on firm performance, relative to more general universities.

Chapple, Lockett, Siegel, and Wright (2005) extends previous research on the relative performance of university technology transfer offices (Thursby and Kemp (2002) and Siegel, Waldman, and Link (2003)) in two important ways. First, the authors report the first evidence based on data from university technology transfer offices in the U.K. A second contribution is that they simultaneously employ parametric and non-parametric methods, which provides for more accurate and robust measurement and "explanation" of relative productivity. Specifically, they compare and contrast stochastic frontier estimation and data envelopment analysis.

Several stylized facts emerge from their empirical analysis. Relative to the U.S., they find much greater variation in relative performance in technology transfer across U.K. universities using both non-parametric and parametric approaches. More importantly, in contrast to the U.S., they find decreasing returns to scale to licensing activity and relatively low levels of absolute efficiency at U.K. universities. This indicates that substantial improvements can be made with respect to the efficiency of U.K. technology transfer offices. Consistent with U.S. evidence, the authors find that organizational and environmental factors explain substantial variation in relative performance. Specifically, they report that older TTOs are less productive than comparable institutions, suggesting an absence of learning effects. Universities located in regions with higher levels of R&D and GDP appear to be more efficient, implying that there may be regional spillovers in technology transfer.

Link and Scott (2005) investigate the conditions when a research joint venture (RJV) will involve a university as a research partner. They hypothesize that larger RJVs are more likely to invite a university to join the venture as a research partner than smaller RJVs because larger

ventures are less likely to expect substantial additional appropriability problems to result because of the addition of a university partner and because the larger ventures have both a lower marginal cost and a higher marginal value from university R&D contributions to the ventures' innovative output. The authors test this hypothesis using data from the National Science Foundation sponsored CORE database, and those data confirm the hypothesis.

VI. Lessons Learned: Normative Applications

Our framework for considering lessons learned is presented in Figure 1. Recall that in the introductory section of the paper we asserted that the effectiveness of university technology transfer should be considered within three contexts: the institutional, organizational, and individual contexts of this activity. Figure 1 suggests that these three contexts are related.

Hence, all three elements must be consistent for technology transfer to be successful, however success is defined by the university and its related stakeholders. For example, research by Markman, Phan, Balkin, and Giannodis (2005), which echoes much of the extant literature, demonstrates that having well intended institutional policies regarding business formation is not sufficient. It has to be supported by the appropriate organizational design choices and further back-stopped by the correct blend of incentives to both the inventors and TTO officers.

Insert Figure 1 About Here

Our review leads us to the normative conclusion that for technology transfer to succeed, it is critical for university administrators to think strategically about the process. Much of the research makes clear that university administrators are often more concerned about protecting intellectual property rights and appropriating the fruits of technology transfer than they are about creating the appropriate context or environment in which such activities are to take place. This implies that they must address numerous formulation and implementation issues, which we now consider in turn.

A key formulation issue is the establishment of institutional goals and priorities, which must be transparent, forthright, and reflected in resource allocation patterns. Establishing priorities also relates to strategic choices regarding technological emphasis (e.g. life sciences vs. engineering and the physical sciences) for the generation of licensing and startup opportunities. Opportunities for technology commercialization and the propensity of faculty members to engage in technology transfer vary substantially across fields both between and within the life sciences and physical sciences. Universities must also be mindful of competition from other institutions when confronting these choices. For example, many universities have recently launched initiatives in the life sciences and biotechnology, with high expectations regarding enhanced revenue and job creation through technology transfer. It is conceivable that any potential financial gains from these fields may be limited.

Resource allocation decisions must also be driven by strategic choices the university makes regarding various modes of technology transfer. As noted previously, these modes are licensing, startups, sponsored research and other mechanisms of technology transfer that are focused more directly on stimulating economic and regional development, such as incubators and science parks. Licensing and sponsored research generate a stream of revenue, while equity

from startups could yield a payoff in the long-term. Universities that stress economic development outcomes are advised to focus on startups since these companies can potentially create jobs in the local region or state. Note also that while a startup strategy entails higher risk, since the failure rate of new firms is quite high, it also can potentially generate high returns if the startup is taken public. It is also important to note that a startup strategy entails additional resources, if the university chooses to assist the academic entrepreneur in launching and developing their startup.

Organizational incentives are also important. The evidence implies that shifting the royalty distribution formula in favor of faculty members (e.g., allowing faculty members to retain 75% of the revenue, instead of 33% of the revenue) would elicit more invention disclosures and greater efficiency in technology transfer. A more controversial recommendation is to modify promotion and tenure guidelines to place a more positive weight on technology transfer activities in such decisions. Clearly, this is a matter that touches the very core of what it means to be an academic researcher and therefore impinges on issues of norms and shared values. However, while we do not underestimate the difficulty, and indeed the appropriateness, with which norms, standards, and values among tenured faculty can be changed, such changes are necessary at institutions that wish to place a high priority on technology commercialization. A more simply recommendation is to switch from standard compensation to incentive compensation for technology licensing officers could also result in more licensing agreements.

The extant research also clearly demonstrates the importance of the effective implementation of technology transfer strategies. Examples of implementation issues include choices regarding information flows, organizational design/structure, human resources management practices in the TTO, and reward systems for faculty involvement in technology

transfer. There are also a set of implementation issues relating to different modes of technology transfer, licensing, start-ups, sponsored research, and other modes that are focused more directly on stimulating economic development, such as incubators and science parks. We now consider each of these in turn, in the context of the quantitative and qualitative analyses cited in previous sections of the paper.

We suggest that for university administrators to fruitfully deal with the implementation issues, they should adopt a value chain perspective of technology transfer. In a corporate setting, the production function is conceptualized as a chain of value adding activities linked by cross functional processes, information flows, material flows, and risk flows. Seen this way, the production function can be reengineered, reordered, resequenced, and even cut short. Similarly, value adding activities can also be sliced into smaller pieces and hived off to partners, suppliers and customers. In the same manner, a university's technology licensing process need not remain exclusively in-house. It is seldom that there is sufficient, technical, legal and managerial expertise in a TTO to manage the scope and depth of technologies and potential technology customers that emanate from a university's laboratories. Hence, by dicing up the set of activities related to technology transfer, from technology identification and selection to technology customer matching, a university can concentrate on those activities it is best equipped to manage and partner with resource providers and outside experts for those areas that it cannot or should not expend resources to build.

For example, human resource management practices appear to be quite important. Several qualitative studies (e.g. Siegel, Waldman, Atwater, and Link, 2004) indicate that there are deficiencies in the TTO, with respect to marketing skills and entrepreneurial experience. Unfortunately, field research (e.g., Markman, Phan, Balkin, and Giannodis, 2005a) has also

revealed TTOs are not actively recruiting individuals with such skills and experience. Instead, representative institutions appear to be focusing on expertise in patent law and licensing or technical expertise.

One method of dealing with this problem is to enhance training and development programs for TTO personnel, along with additional administrative support for this activity, since many TTOs lack sufficient resources and competencies to identify the most commercially viable inventions. Training in portfolio management techniques would be extremely useful in this context. Selection, training, and development of TTO personnel with such portfolio management skills are necessary if the screening mechanism is to be improved. Furthermore, incentives should be directed towards creating immediate feedback and rewards (i.e. cash) to motivate TTO personnel to improve their expertise through training.

Another solution, taking a value chain approach, is to partner with technology experts in corporations or consulting firms. Research has shown that career opportunities for university technology licensing officers are limited and often of short duration (Siegel, Waldman, Atwater, and Link, 2004; Markman, Phan, Balkin, and Giannodis, 2004a), which implies recruiting appropriate talent is at best a stochastic outcome.

We have shown that organizational incentives are important. The evidence implies that shifting the royalty distribution formula in favor of faculty members (e.g., allowing faculty members to retain 75% of the revenue, instead of 33% of the revenue) would elicit more invention disclosures and greater efficiency in technology transfer. A more controversial recommendation is to modify promotion and tenure guidelines to place a more positive weight on technology transfer activities in such decisions. We believe that such changes are warranted at institutions that wish to place a high priority on technology commercialization, although we do

not underestimate the difficulty of changing norms, standards, and values among entrenched tenured faculty. Finally, a switch from standard compensation to incentive compensation for technology licensing officers could also result in more licensing agreements.

Finally, the extant research suggests that improving information flows between academics and the university administration matters to technology transfer effectiveness. In the first instance, technology licensing officers and university administrators share an interest in promoting technology commercialization and therefore should devote more effort to eliciting invention disclosures. While part of the problem with poor disclosure outcomes has to do with faculty incentives (publications are usually regarded as mutually exclusive to patents), we surmise from the research that a greater part has to do with the lack of formal and rich communication channels between the university laboratories and the TTO.

Maintaining communication bandwidth is resource intensive (in time) for the researcher. The filing reports and giving seminars to potential technology licensees is usually a strong deterrent to faculty, even if they are interested in profiting from their discoveries. The opportunity costs are such (by some estimates, 8 peer reviewed papers for each patent filed) that the 'hurdle rate' for an embryonic discovery would be so high as to minimize potential blockbusters that would only be apparent with additional, usually incremental, research. Hence, the institution must be prepared to bear the costs of maintaining communication, such as providing administrative support within the individual laboratories to manage information flows and paperwork for licensing projects. Related to this, it is also important to provide information and support for faculty members who express an interest in forming a start-up. Given that business formation requires skills that academic scientists typically do not possess and they involve activities that are somewhat alien to their culture (e.g., assessing market demand for their

invention), universities could partner with and reward business school faculty to train and mentor potential academic entrepreneurs.

VII. Lessons Learned: Theoretical Implications

Our review clearly suggests some theoretical frameworks that can be applied to furthering the research in this field. Because the work is still relatively nascent, much of it has been descriptive and approached from the perspective of inventorying the phenomenon. However, we have also reviewed good examples of theoretically based approaches. For example, the notion of path dependency goes a long way to explain the persistence difference in commercialization success rate between experienced universities and those that are new to the game. In contrast to phenomena that can be described by productivity frontiers, there does not appear to be evidence of a ‘regression to the mean’ (or decreasing returns) in technology transfer. One reason may be that we have not been able to measure over a long enough time period but a more compelling rationale may be that TTOs, over time, learn how to do this well and to the extent that such learnings become embedded in an institutional context, can distance themselves from those that are new to the activity. In addition, because of the geographically localized nature of successful technology transfer, it appears that the situations into which such expertise can be successfully transplanted may be limited. Hence, the use of institutional theory and evolutionary economics perspectives to explain the persistence of differences in effectiveness across regions may be a fruitful direction in which to take the research related to regional development and university technology transfer.

At the level of the organization, our review has been clear that the consistency and congruency of organization design, incentive systems, information process capacity, and

organization-wide values matter a great deal in technology transfer success and new venture creation. Employ well received theory from the organization sciences, such as the resource based view of the firm, structural contingency theory, and social network theory may provide excellent foundations for deriving even more sophisticated insights in future research, particularly because the phenomenon is going international and therefore, attempts to generalize theory must take a more systematic tact than has heretofore been employed in the literature. In particular, if we are careful to define the dependent variable as an economic outcome (technological commercialization) of a largely socio-psychological phenomenon (university scientists discovering knowledge), we should be able to apply standard organization theories in the non-profit setting of a university.

At the individual level of analysis, there is an emerging literature that attempts to model the TTO-scientist and TTO-university relationship from an agency theory perspective. This is a highly useful direction to pursue, which we believe can be taken a step further. Assumptions relating to principal-agent decisions are based largely on Bayesian rationality. Based on recent research on prospect theory, we can incorporate the notion of prior losses or gains into the choice models (e.g., to faculty member's decision to disclose or not to disclose an invention, to license or not license a technology; or to launch a new venture or not) to the problem of opportunity costs faced by the scientists and transactions costs faced by the university and/or commercial enterprise. The specificity with which we can theoretically specify the TTO relationships will allow us to seek latent constructs that determine the institutional, organizational and individual relationships to technology transfer effectiveness, and hence build more predictive normative models.

VIII. Conclusions

In the aftermath of the Bayh-Dole Act, other supporting legislation, and an increase in public–private research partnerships, there has been a rapid increase in technology commercialization at universities. Universities are now in the business of managing intellectual property portfolios and are often aggressively attempting to commercialize discoveries from their laboratories. This activity is driven, in part, by anecdotes relating to the financial promise of university technology transfer, i.e., the lucrative stream of licensing revenue and IPO-related wealth resulting from Internet search engines and browsers, Gatorade, gene sequencing, and drug discovery. Universities have also been compelled, especially in the U.K., to pursue commercialization due to shrinking endowments, reductions in government funding, and increased operating costs.

Unfortunately, for many institutions, “success” in university technology transfer has not been achieved. In an effort to improve our understanding of why such efforts have failed, we presented an extensive review and synthesis of much of the more notable recent research on universities technology transfer. Our contribution is to offer a systematic framework for considering the issues to university administrators, policymakers, and economists.

This framework has also allowed us to draw some preliminary normative conclusions about what is required for success in technology transfer. Generally, our conclusion, as expressed in Figure 1, consists of three parts. There are clearly defined institutional, organizational and individual factors to be considered simultaneously when trying to understand why technology transfer works or does not work. Second, although these factors appear to be common across universities, the importance to which they matter for effectiveness at a

particularly university is likely to vary by the history, academic value system, and technological depth of the institution.

Third, it is important to note that the “outputs” of university technology transfer depend on the quantity and quality of discoveries. This highlights the importance of the “suppliers” of new technologies—the faculty members who conduct research in the laboratory and (in theory) disclose inventions to the TTO. As universities strive to improve the success rate of their commercialization activities, they must preserve the inquiry-based research environment that currently exists in the university laboratory. The substitution of less risky, applied research for high risk, basic research would result in fewer “home-run” commercializable inventions, which would be inconsistent with the culture of entrepreneurship necessary for new business formation.

Finally, in order to further advance the extant literature, we encourage researchers to consider applying systematic theoretical frameworks in describing the relationships presented in Figure 1. More specifically, we believe that by employing theoretical perspectives appropriate to the three levels of analyses and by improving our specification of the dependent variable, even more nuanced policy recommendations can result from the research. The importance of this extension cannot be understated, as the phenomenon of university technology transfer goes global and the competition for ideas, resources and licensing revenues accelerates with the participation of foreign governments and non-governmental advocacy organizations. The promise of university technology transfer may indeed someday be achieved.

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Table 1
Quantitative and Qualitative Research on the Effectiveness of
Licensing of University-Based Inventions in the U.S. and U.K.

Author(s)	Data Sets	Methodology	Key Findings
Jensen, and Thursby (2001)	N/A	Theoretical Analysis	Faculty Involvement in the Licensing of a University-Based Technology Increases the Probability of Success
Thursby, Jensen, and Thursby (2001)	AUTM, Authors' Survey	Descriptive Analysis of Authors' Survey/ Regression Analysis	Inventions Tend to Disclosed At An Early Stage of Development; Elasticities of Licenses and Royalties With Respect to Invention Disclosures Are Both Less Than One; Faculty Members Are Increasingly Likely to Disclose Inventions.
Bercovitz, Feldman, Feller, and Burton (2001)	AUTM and Case Studies, Interviews	Qualitative and Quantitative Analysis	Analysis of Different Organization Structures for Technology Transfer at Duke, Johns Hopkins, and Penn State; Differences in Structure May Be Related to Effectiveness
Thursby and Kemp (2002)	AUTM	Data Envelopment Analysis And Logit Regressions on Efficiency Scores	Faculty Quality and # of TTO Staff Has a Positive Impact on Licensing; Private Universities Appear To Be More Efficient Than Public Universities; Universities With Medical Schools Less Efficient
Friedman and Silberman (2002)	AUTM, NSF, NRC, Milken Institute "Tech-Pole" Data	Regression Analysis- Systems Equations Estimation	Higher Royalty Shares For Faculty Members Are Associated With Greater Licensing Income
Carlsson and Fridh (2002)	AUTM	Linear Regression	Research Expenditure, Invention Disclosures, and Age of TTO Have a Positive Impact on University Licensing
Siegel, Waldman, and Link (2003)	AUTM, NSF, and U.S. Census Data, Interviews	Productivity of University Licensing; -Stochastic Frontier Analysis and Field Interviews	TTOs Exhibit Constant Returns to Scale With Respect to the # of Licensing; Increasing Returns to Scale With Respect to Licensing Revenue; Organizational and Environmental Factors Have Considerable Explanatory Power
Lach and Schankerman (2004)	AUTM, NSF, NRC,	Regression Analysis	Higher Royalty Shares For Faculty Members Are Associated With Higher Licensing Income

Table 1 (cont.)
Quantitative and Qualitative Research on the Effectiveness of
Licensing of University-Based Inventions in the U.S. and U.K.

Author(s)	Data Sets	Methodology	Key Findings
Chapple, Lockett, Siegel, and Wright (2005)	U.K.-NUBS/ UNICO Survey-ONS	Data Envelopment Analysis and Stochastic Frontier Analysis	U.K. TTOs Exhibit Decreasing Returns to Scale and Low Levels of Effectiveness; Organizational and Environmental Factors Have Considerable Explanatory Power
Link and Siegel (2005)	AUTM, NSF, and U.S. Census Data, Interviews	TFP of University Licensing -Stochastic Frontier Analysis	Land Grant Universities Are More Efficient in University Technology Licensing; Higher Royalty Shares For Faculty Members Are Higher Levels of Effectiveness in University Technology Licensing
Debackere and Veugelers (2005)	Interviews and Survey Data of 11 European Research Universities	Case Studies	Universities Allocating a Higher Percentage of Royalty Payments to Faculty Members Tend to be More Effective in Technology Transfer. A Critical Success Factor is What They Call a “Decentralized Management Style.”
Chapple, Lockett, Siegel, and Wright (2006)	U.S.-AUTM, U.K.-NUBS/ UNICO Survey-ONS	Stochastic Distance Function	U.S. Universities Are More Efficient than U.K. Universities; TTOs Exhibit Decreasing or Constant Returns to Scale. Universities With Medical Schools And Incubators Are Closer to Frontier

Table 2
Selected Studies of Science Parks in the U.S. and U.K.

Author(s)	Data Sets	Methodology	Key Findings
Westhead and Storey (1994)	Longitudinal Dataset Containing Information on the Characteristics and Performance of <u>Firms</u> Located On and Off Science Parks in the U.K.	Analysis of the Probability of Survival	No Difference in the Survival Rates of Firms Located on University Science Parks and Similar Firms Not Located on University Science Parks
Westhead, Storey, and Cowling (1995)	Longitudinal Dataset Containing Information on the Characteristics and Performance of <u>Firms</u> Located On and Off Science Parks in the U.K.	Multivariate/. Logistic Regression Analysis	Sponsored Science Park Environments Did Not Significantly Increase the Probability of Firm Survival
Westhead, and Cowling (1995)	Longitudinal Dataset Containing Information on the Characteristics and Performance of <u>Firms</u> Located On and Off Science Parks in the U.K.	Analysis of Descriptive Statistics	No Difference in Employment Growth Rates of Firms Located on University Science Parks and Similar Firms Not Located on University Science Parks

Table 2 (cont.)
Selected Studies of Science Parks in the U.S. and U.K.

Author(s)	Data Sets	Methodology	Key Findings
Siegel, Westhead, and Wright (2003)	Longitudinal Dataset Containing Information on the Characteristics and Performance of Firms Located On and Off Science Parks in the U.K.	Productivity of Research Efforts/Estimation of R&D Production Function	Science Park firms are More Efficient Than Non-Science Park Firms in Research (i.e., Generating New Products and Services and Patents)
Link and Link (2003)	Association of University Related Research Parks (AURRP) Survey of U.S. parks; Survey of Park Directors	Analysis Hazard Function Analysis	Real Estate Parks Are The Fastest Growing Type of Park, But Their Growth Is Not Related to Being Close to a University
Link and Scott (2003)	Association of University Related Research Parks (AURRP) Survey; Authors' Survey of University Provosts /Hazard Function Regression Analysis/Ordered Probit Equation Estimation	Hazard Function Analysis Employment Growth /Six Dimensions of the Academic Mission of the University:	Proximity to a University and the Availability of Venture Capital Have a Positive Impact on Growth; Science Park Enables Universities to Generate More Publications and Patents, More Easily Place Graduates, and Hire Preeminent Scholars

Table 2 (cont.)
Selected Studies of Science Parks in the U.S. and U.K.

Author(s)	Data Sets	Methodology	Key Findings
Link and Scott (2004a)	Association of University Related Research Parks (AURRP) Survey of U.S. Parks; Authors' Survey of University Provosts	Regression Analysis	There is a Positive Association Between the % of University-Based Start-ups and the Age of the Park, the Quality of the Research Environment at the University, Proximity to the University, and Whether the Parks Has a Biotechnology Focus
Link and Scott (2006)	Authors' Survey of U.S. Science parks, Supplemented by data from the Internet	Regression Analysis	The Following Factors Are Associated With Science Park Growth: Proximity to the University, Whether the Park is Managed by a Private Organization, Whether the Park Has a Focus on Information Technology

Table 3
Quantitative and Qualitative Research on University-Based
Entrepreneurial Activity in the U.S. and U.K.

Author(s)	Unit of Analysis	Data/ Methodology	Key Findings
Louis, Blumenthal, Gluck, and Stoto (1989)	Faculty Members in the Life Sciences	778 Faculty Members from 40 Universities/ Regression Analysis	Key Determinant of Faculty-Based Entrepreneurship: Local Group Norms; University Policies and Structures Have Little Effect
Zucker, Darby, and Brewer (1998)	Relationships Involving "Star" Scientists and U.S. Biotech Firms	Scientific Papers Reporting Genetic-Sequence Discoveries, Data on Biotech Firms from the North Carolina Biotechnology Center (1992) & Bioscan (1993)/Count Regressions	Location of Star Scientists Predicts Firm Entry in Biotechnology
Zucker, Darby, and Armstrong (2000)	Relationships Involving "Star" Scientists and U.S. Biotech Firms	Scientific Papers Reporting Genetic-Sequence Discoveries, Data on Biotech Firms from the North Carolina Biotechnology Center (1992) & Bioscan (1993)/Count Regressions	Collaboration Between Star Scientists and Firm Scientists Enhances Research Performance of U.S. Biotech Firms, As Measured Using Three Proxies: Number of Patents Granted, Number of Products in Development, and Number of Products on the Market
Audretsch (2000)	Entrepreneurs in the Life Sciences	101 Founders of 52 Biotech Firms/Hazard Function Regression Analysis	University Entrepreneurs Tend to Be Older, More Scientifically Experienced

Table 3 (cont.)
Quantitative and Qualitative Research on University-Based
Entrepreneurial Activity in the U.S. and U.K.

Author(s)	Unit of Analysis	Data/ Methodology	Key Findings
Zucker and Darby (2001)	Relationships Involving “Star” Scientists and Japanese Biotech Firms	Data on Biotechnology Firms and the Nikkei Biotechnology Directory	Collaboration Between Star Scientists and Firm Scientists Enhances Research Performance of Japanese Biotech Firms, As Measured Using Three Proxies: Number of Patents Granted, Number of Products in Development, and Number of Products on the Market
Franklin, Wright, and Lockett (2001)	TTOs and University-Based Startups	Authors’ Quantitative Survey of U.K. TTOs	Universities That Wish to Launch Successful Technology Transfer Startups Should Employ a Combination of Academic and Surrogate Entrepreneurship
Lockett, Wright, and Franklin, (2003)	TTOs and University-Based Startups	Authors’ Quantitative and Qualitative Surveys of U.K. TTOs	Universities That Generate the Most Startups Have Clear, Well-Defined Spinout Strategies, Strong Expertise in Entrepreneurship, and Vast Social Networks
Di Gregorio and Shane (2003)	U.S. University-Based Startups	AUTM Survey/Count Regressions of the Determinants of the # of Startups	Two Key Determinants of Start-up Formation: Faculty Quality and the Ability of the University and Inventor(s) to Take Equity in a Start-up, in Lieu of Licensing Royalty Fees; A Royalty Distribution Formula that is More Favorable to Faculty Members Reduces Start-up Formation
Lockett and Wright (2005)	TTOs and University-Based Startups	Quantitative Survey of U.K. TTOs/ Count Regressions of the Determinants of the # of Startups	A University’s Rate of Start-up Formation is Positively Associated with Its Expenditure on Intellectual Property Protection, the Business Development Capabilities of TTOs, and the Extent to Which its Royalty Distribution Formula Favors Faculty Members
Nerkar and Shane (2003)	University-Based Startups	Longitudinal Data from MIT Startups/ Hazard Function Analysis	“Radicalness” of the New Technology and Patent Scope Increase the Probability of Survival More in Fragmented Industries than in Concentrated Sectors ⇒ Effectiveness of Technology Strategies of New Firms Appears to Depend on Industry Conditions
O’Shea, Allen, and Arnaud (2005)	U.S. University-Based Startups	AUTM Survey/Count Regressions of the Determinants of the # of Startups	A University’s Previous Success in Technology Transfer is a Key Determinant of Its Rate of Start-up Formation

Table 3 (cont.)
Quantitative and Qualitative Research on University-Based
Entrepreneurial Activity in the U.S. and U.K.

Author(s)	Unit of Analysis	Data/ Methodology	Key Findings
Markman, Phan, Balkin, and Gianiodis (2004a)	U.S. TTOs and University-Based Startups	AUTM Survey, Authors' Survey/Linear Regression Analysis	Equity Licensing and Startup Formation Are Positively Correlated With TTO Wages; Uncorrelated or Even Negatively Correlated With Royalty Payments to Faculty Members
Markman, Phan, Balkin, and Gianiodis (2005b)	U.S. TTOs and University-Based Startups	AUTM Survey, Authors' Survey/Linear Regression Analysis	There Are Three Key Determinants of Time-to Market (Speed): TTO resources, Competency in Identifying Licensees, and Participation of Faculty-Inventors in the Licensing Process
Markman, Phan, Balkin, and Gianiodis (2005a)	U.S. TTOs and University Startups	AUTM Survey, Authors' Survey/Linear Regression Analysis	The Most Attractive Combinations of Technology Stage and Licensing Strategy for New Venture Creation-Early Stage Technology and Licensing for Equity-Are <u>Least</u> Likely to Favored by the University (Due to Risk Aversion and a Focus on Short-Run Revenue Maximization)
Lockett and Wright (2005)	TTOs and University-Based Startups	Authors' Quantitative Survey of U.K. TTOs/ Count Regressions of the Determinants of the # of Startups	A University's Rate of Start-up Formation is Positively Associated with Its Expenditure on Intellectual Property Protection, the Business Development Capabilities of TTOs, and the Extent to Which its Royalty Distribution Formula Favors Faculty Members
O'Shea, Allen, and Arnaud (2005)	U.S. University-Based Startups	AUTM Survey/Count Regressions	A University's Previous Success in Technology Transfer is a Key Determinant of Its Rate of Start-up Formation
Leitch and Harrison (2005)	U.K. University-Based Startups	Case Studies of U.K. University Spinouts	In Non-technology Intensive Regions, TTOs Tend to Focus on Regional Economic Development and Commercialization of University-Based Research
Thursby and Thursby (2005)	Faculty Members at U.S. Universities	Authors' Database of Over 4500 Faculty members/ Regression Analysis	Female Faculty Members Are Less likely to Disclose Inventions than Male Faculty Members, Even They Appear to Publish at Roughly the Same Rate; However, There is Evidence That the Rate of Disclosure Activity of Women and Men Is Converging Over Time

Table 3 (cont.)
Quantitative and Qualitative Research on University-Based
Entrepreneurial Activity in the U.S. and U.K.

Author(s)	Unit of Analysis	Data/ Methodology	Key Findings
Powers, and McDougall. (2005a)	U.S. University-Based Startups	AUTM/ Regression Analysis	University Financial, Human Capital, and Organizational Resources Are Significant Predictors of the Rate of Start-up Formation and the Number of Initial Public Offering (IPO) Based on a University Technology License
Powers, and McDougall. (2005b)	U.S. University-Based Startups	AUTM/ Regression Analysis	Universities That Have More Supportive Licensing and Entrepreneurial Policies Have Better Technology Transfer Performance
Brouwer (2005)	University-Based Startups	Theoretical analysis	“Outside” Inventors Have Stronger Incentives to Invent Than Incumbents. Embryonic Inventions Are Best Commercialized by New Enterprises Due to the Uncertainty of Their Outcomes. Cooperative Invention and Commercialization Might Boost Consumer Welfare But provides Little Incentive to Invent
Campbell (2005).	U.K. Universities	Case Studies	Asserts That U.K. Universities Have Developed New Ways To Create Value Through Technology Commercialization. This is Attributed to New Initiatives That Promote Flexibility and Cutting-Edge Approaches
Markman, Gianiodis and Phan (2006)	TTOs and University-Based Startups	AUTM, Interviews, Surveys, TTO Documents/ Regression Analysis and Content Analysis	“Gray Market” Activity is Reduced when TTOs are Professionalized, but Such Activity is Associated With More Valuable Discoveries and Heightened Entrepreneurial Activities
Renault (2006)	Faculty Members	Interviews	The Most Significant Determinant of Entrepreneurial Behavior Is a Professor’s Belief About the Proper Role of Universities in the Dissemination of Knowledge. Institutional Policies, Such as Royalty Distribution Formulas, Are Also Important

Figure 1

The Institutional, Organizational and Individual Contexts of Technology Transfer Effectiveness

