

The Complex Relationship Driving Technology Transfer: The Potential Opportunities Missed by Universities

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ABSTRACT

Since the Bayh-Dole act, decreased federal funds to research-intensive and extensive universities resulted in a search for alternative resources to continue research activities. Changes made by higher education institutions in strategic orientation initiated the development of technology transfer offices designed to support patent development, licensure to corporations, and spin-off of entrepreneurial efforts. Researchers seek explanatory models to understand variances in university success; however, current models lack full descriptive power. Therefore, we first identify the current research base on technology transfer; propose an alternative view; and, recommend propositions and future research.

Introduction

As early as 1996, the AUTM reported that “[t]echnology transfer programs are integral to the academic institution's mission: education, research, and public service, in that they provide:

- “• A mechanism for important research results to be transferred to the public;
- Service to faculty and inventors in dealing with industry arrangements and technology transfer issues;
- A method to facilitate and encourage additional industrial research support;
- A source of unrestricted funds available to the institution for additional research;
- A source of expertise in licensing and industrial contract negotiation;
- A method by which the institution can fulfill the requirements of P.L. 96-517 and P.L. 98-620” (AUTM, 1996).

Since the Bayh-Dole act, decreased federal funds to research-intensive and extensive universities resulted in a search for alternative resources to continue research activities. Between 1996 and 2005, universities in the AUTM Licensing STATT report an increase in total research expenses from \$21.4 to \$44.2 billion while revenues have increased from \$.59 to \$1.98 billion. However, these figures may misled since the number of

reporting institutions increased from 173 in 1996 to 214 in 2005; the median expenses were \$78.6 million and \$125.6 million respectively. Given the 60% increase in the amount of research investment that higher education institutions conduct, it is reasonable to state that these institutions view licensing and technology transfer (TT) as a source of revenue. Furthermore, attempts to stress the societal impact, the public service dimension, of technology license resulted in Association of University Technology Managers (AUTM) to suggest *In the Public Interest: Nine Points to Consider in Licensing University Technology* specific licensing areas that will facilitate the increase in social welfare. However, as suggested by the returns above, current TT models pursued by universities are shortsighted and produce marginal benefits for all but a select few universities. As if to validate the 'holy trinity' of government-academia-business, in 2007 Senate Bill 1301, "Building a Stronger America Act," was introduced to the Senate to fund regional economic development centers to facilitate T2 between the three constituencies (Senate, 2007).

Many universities use extremely complex systems that take years to reach a licensing arrangement. Others build walls between academia and TT that nearly eliminates any incentive for faculty members to participate in the process. Additionally, research suggests that federal, state, and local government support is necessary to nurture technology development; provide early stage financing for start-ups; and, attract entrepreneurs and other necessary talent to a region. In this paper, the foundation for a theory regarding why more thoughtfully developed TT policies that includes the type of incentives, partnerships, and researcher motivations that may help the trinity as a whole derive increased benefits from the efforts of university-based researchers and help all parties involved achieve greater success. For the remainder of the paper we discuss informative background literature on technology transfer; suggest an alternative view with propositions; and, discuss the implications and suggest areas for future research.

Background

Different levels of success by universities and their technology commercialization efforts have resulted in much research (e.g., Etzkowitz et al., 1998; Malairaja & Zawdie 2004; Markham, 2002; Medda et al., 2006; Noll, 1998; Phan & Siegel, 2006; Porter, 2003; Porter & Stern, 2001; Slaughter & Leslie, 1997; Teece, 1986). Reported findings for the variance in performance between universities include regional synergies, researcher motivation, and technology readiness levels (TRL) to name only a few. With respect to regional synergies, local actors such as entrepreneurs, researchers, university officials, and politicians help to trigger economic growth. Researchers have identified two stages through which an economy progresses in order to trigger growth: an institutional phase in which the "raw materials" such as support services, research facilities, and scientists are brought together; and, an entrepreneurial phase whereby research is spun off into companies thanks to a nexus of business professionals, venture capital, and governmental policy support (Markham, 2002; Phan & Siegel, 2006; Porter, 2003).

Academic institutions are essential to the transition from the institutional phase to the entrepreneurial phase. Institutions of higher learning often result in technology transfer

offices (TTO), science parks, spin-off firms, and other collaborations between business and academia (Etzkowitz, 1999; Phan & Siegel, 2006; Siegel et al., 2004). University-based technology does not generally produce immediate results given the generally low TRL, but may have a long-term impact upon the growth of a region (Florida & Cohen, 1999). In order to capitalize on college/university technological development capacity, a region must develop the mechanisms to capture and absorb research spillovers. The quality of the social capital in a region will largely determine whether the university-based entrepreneurial activity “sticks to the region or slides away to more fertile ground” (Farrant, 2005; Kodama & Branscomb, 1999).

Regional Impact

Some regions are more successful at capturing the economic benefits of new technologies and adapting to changes in market demand (e.g., Furman, Porter & Stern, 2002; Niosi and Banik, 2005; Porter 2003). Research in this area draws on Alfred Marshall's (1968) seminal piece on industrial districts. Marshall observed that small firms in the same industry realized economies of scale external to the firm via co-location. Subsequent research has built on Marshall's emphasis on common infrastructure, business services, specialized labor, and local know-how.

Research on the effectiveness of university efforts on regional development is mixed. Beeson and Montgomery (1993) found that a university's presence affects a region's income, employment rate, or net migration rate, while Florax and Folmer (1992) found a weak relationship on knowledge effects (the inclusion of university-based knowledge into the local economy). In the latter research, spending by students and university employees was found to have a much greater impact on the local economy than did any university related knowledge spillovers (Florax & Folmer, 1992). Other researchers note that universities produce large effects on the presence of high-tech production, start-ups, and R&D facilities (Audretsch, Lehmann, & Warning, 2005; Malecki, 1991) but only in established high-technology areas. In research conducted by Anselini et al. (1997), a strong relationship between university presence and innovation activity was found within a 50-mile radius of the institutions. Similarly, Varga (2000) concluded that innovative activity concentrates in areas where academic research takes place; this finding was also supported by Peri (2005). Even controlling for other variables, Varga (2000) found that the primary factor influencing innovation activity is the presence of a university.

Contrary to the findings presented above, Feldman (1994) found that while Johns Hopkins University develops some of the nation's most cutting edge medical technologies, most of the development of the technologies (and the economic benefits that go along with that development) are captured in other cities; Baltimore did not have the structure, the entrepreneurial culture and venture capital investment to capitalize on the opportunities present. Furthermore, Johns Hopkins' relationship with the federal government hindered their ability to commercialize their research. Feldman found that since much of the research conducted at Johns Hopkins was funded by the Department of Defense and classified, the results were not available for commercialization and resulted in Baltimore's lag relative to other regions with major research institutions. The

findings presented here suggest that the type of research that the university conducts impacts the success of regional development.

Other studies consider the importance of geographic proximity to universities in spin-off location decisions. This is particularly important when frequent interaction with faculty consultants is required (Mansfield & Lee, 1996). What happens when the university and the company are in different locations? Because high-tech startup companies do not progress in a linear fashion, the significance of co-location is difficult to measure. Fogerty and Sinha (1999) found that geographic proximity confers only a temporary advantage to regions and industries. To capture the long term benefits of TT, regional efforts targeting start-up companies, providing local industrial and technology assistance to local industry, and R&D lab expansion are required.

University Motivation

The university mission includes education, research, the exchange of ideas among scholars, and at some institutions the development of technological innovation as public benefits. Additionally, although spin-offs go beyond the core function of the university, the tangible results include the formation of new jobs, businesses and even industries which when adeptly-handled benefit the university and its community. Markman et al. (2005) state that given their creation and consumption of new knowledge universities find themselves as major policy issues. Hence, we suggest that step one in the economic development of a community is the formation a TTO. Some schools fully integrate this function and have professionals who work directly with faculty, and handle all related functions from patenting and licensing to entrepreneurial assistance. Other schools rely on a traditional ivory-tower approach and view TT as a distraction from the principal responsibilities of faculty. Generally, these institutions will limit their TT efforts to industry-sponsored research and provide only minimal assistance. Traditionally, the objective of TT is to sell intellectual property to the highest bidder and typically takes faculty out of the equation. However, as Feller's (1986) study showed, it is unlikely that TT will generate significant royalty revenues for all but a select few universities.

When working with cash-starved start-up companies, universities often take equity instead of cash and universities with greater experience are more willing to experiment with equity financing (Feldman et al., 2002). Researchers identified three factors that increase firm formation: intellectual eminence, university policy regarding equity investment, and a low share of royalties for the inventor (DiGregorio & Shane, 2003). Elite research universities generated more patentable intellectual property due to the presence of arguably better researchers. Additionally, investors use university status as a signal in evaluating which firms they finance. Universities which accept equity financing generate more start-up companies with greater liquidity. Finally, the higher percentage of royalties to the researcher was inversely related to the start-up rate (in other words, the higher the royalty rate going to the faculty member, the more likely he/she would like to license the invention to an established company). One study found little or no significance in the availability of venture capital financing and the commercial orientation of university R&D (what industries they focused on). Their study did not

examine micro level factors such as the nature of the technology and the experience level of the entrepreneurs interested in the licenses.

Eminence, the reputation that the university carries, is yet another factor that contributes to TT (Di Gregorio & Shane, 2003). For instance, MIT has a nearly mythical reputation as an institution which partners with industry to develop university-based technologies. Dating back to 1925, the university formed the Northeast Council to improve business conditions and attract new industries to the Boston area. Local business and political leaders recognized the benefits of academic research labs, and urged local businesses to take advantage of what was available as a result of university research. MIT's administrators later realized that the greatest obstacle to TT was the lack of financing available to start-up companies. Therefore, MIT helped found American Research and Development, the nation's first venture capital firm. MIT not only invested money into this venture, but MIT professors also served as advisors and directors (Etzkowitz, 2002).

Kenney and Goe (2002) conducted a comparative study of culture and organizational rules on academic entrepreneurship in Stanford and UC Berkley's engineering and computer science departments, finding that the environment at each institution had a strong influence upon the level of startup activity. At Stanford, academic entrepreneurship thrives, while at UC Berkley, there is little or no support for academic entrepreneurship. Much of this attribution comes from the presumption that faculty at a state university are civil servants and should not benefit from the results of their work. Conversely, Stanford University is a champion of firms founded by students and faculty; the university allows professors to serve as corporate officers and accept equity in lieu of cash. Academic entrepreneurs (individuals who are both associated with a university and a start-up firm), the individuals turning knowledge into economic activity, must be understood as part of the innovative mix of local agents that contribute to high-tech development (Feldman, 2001). Although university administrators are interested in increased economic returns from academic research, little research has been done on the characteristics and local requirements of academic entrepreneurs.

Other researchers have examined the cultural and attitudinal dimension of academic behavior and how faculty members respond to increasing institutional demands for expanded industry interaction. Research has shown that faculty members tend to prefer consulting and consider TT as a public good, while they generally disapprove of universities taking equity in start-up companies. This is because such policies lead to a perceived conflict with basic research agendas in higher education institutions, increased secrecy requirements (companies eschew "free exchanges" of ideas until the intellectual property is secure), and the potential departure of faculty and graduate students to commercially valuable projects (Lee, 1999).

State and Local Efforts

Industrial restructuring and a downward cycle in the traditional economic structure of numerous older regions of the United States during the 1980s led to capital flight,

business failures, population loss, unemployment, decreasing personal income, and a weakened financial base. To help induce investment, create new jobs, and bolster the local tax base, many state and local politicians turned to high-tech economic development strategies, including university-industry partnerships. This was due in part to the high profile successes of regions including Silicon Valley and Boston's Route 128 corridor (Golob et al., 1999; Harrison, 1994; Saxenian, 1994).

The effectiveness of these strategies has not been proven, yet politicians still find them attractive for various reasons. First, the introduction of innovative products and processes may upgrade the region's industrial base and help to grow both the employment and tax base. Second, high-tech firms tend to provide high wage jobs that also grow the tax base. Third, high-tech industries provide innovative products and services that stimulate demand and create expanded market opportunities, helping to draw new sources of capital into a region. Fourth, by nurturing innovative research, new sectors may emerge and attract related companies to a region, creating a cluster and providing the benefits of an expanded skilled work force, specialized suppliers, and support services. Fifth, high-tech firms offer graduates from local universities the opportunity to remain in a region and may also serve to attract highly educated individuals from other regions.

However, the strategy of attracting high-tech companies does not offer instant relief or turnaround to local economic declines. In the beginning, these companies typically offer fewer jobs than manufacturing firms and have a lower multiplier effect on a region. Additionally, because these jobs typically require highly specialized skills, there are few opportunities for displaced low skill workers. Furthermore, high-tech companies tend to have an affinity for new regions without a dedicated infrastructure. Finally, high-tech sectors are also vulnerable to business cycles and their decline can also have an adverse effect on a region (Goldstein & Luger, 1993).

Two studies conducted in the 1980s focused on state efforts to assist universities in developing high-tech commercial enterprises (Schmandt & Wilson, 1987; Vaughn & Pollard, 1986). The results of these studies showed that state support helped in regions that already had a well-developed technical infrastructure. Regions with less critical mass, however, did not derive the same amount of impact from such programs. Smith and Florida (2000) found that the amount of venture capital invested increased by 800%, from \$4.5 billion to \$37 billion between 1980 and 1995. However, even with this growth in available dollars, venture capital firms have remained very regional. For example, 64% of venture capital funds are managed in three states: California with 29%, New York with 21%, and Massachusetts with 14%. The concentrations are even higher at the metropolitan level with three metro areas: San Francisco, New York, and Boston hosting more than 50% of all venture capital firms. Furthermore, the bulk of funding in the US flows to two centers, Silicon Valley and Route 128.

Bingham and Mier's research (1993) calls into question the state's role as an entrepreneurial agent in promoting start-up activity. While there is a significant length of time required for most high-tech companies to bring a product to commercialization, most politicians are primarily interested in showing results prior to the next election

cycle. Due to such discrepancies, public officials often look for economic programs that deliver quick results (Dewar, 1998) to quickly capture the benefits. However, start-up companies rarely produce tangible payoffs in this short time span. Officials must also be knowledgeable about the technologies being developed and the capabilities of the local economic structure and be able to structure incentives accordingly. This is difficult given that most public officials are not schooled in the latest technical requirements.

The TT Process

The TT process is a complex matter that includes legal issues, technical complexities, financial calculations, and marketing. Institutions of higher learning have developed a number of approaches. Some authors suggest a purely linear model of TT (Siegel et al., 2003). The linear model of TT suggests a process from discovery, disclosure, evaluation, patent, market, negotiation and then license. However, Autio et al. (2004), McAdam et al. (2006), and Minutolo and Lipinski (2006) suggest that the linear model of TT is outdated and that a network theory approach is more appropriate. A general overview of the steps of the network theory approach is presented below as discreet units; however, we acknowledge that the process is not as isolated as this process suggests.

Universities select which technologies they choose to patent. Many ideas put forward by faculty are not pursued for various reasons. The first step is a disclosure stage in which faculty members submit disclosure to the university TT office indicating that they believe they have discovered a patentable technology. The TT office then decides if they want to pursue a patent. Questions that must be answered include such issues as the commercial potential of the invention and the time it will take to get a product to market. Assuming that the TT office decides to pursue a patent, the patenting process will generally cost about \$10,000 to secure a patent. Due to this expense, a TTO must be selective. Every idea that is put forward cannot be pursued; if complex issues arise, the patent could cost more than \$20,000 to pursue (Lowe, 2003).

In the licensing stage, universities have the potential to earn revenue. Some schools engage in little more than a “shotgun” approach, but this is generally not effective (Hsu & Bernstein, 1997). Often, the best sources for finding of a potential licensor is the inventor himself or herself, since such individuals are often the best networked person and the most familiar with the work going on in the field. According to a study by Jansen and Dillon (1999), 54% of successful licensing leads come from the scientists themselves. In some cases, the inventor himself or herself may request a license to develop the technology with a spin off.

Universities can select from four different types of licensing agreements, including exclusive, non-exclusive, co-exclusive, and option (Louis, 2000). Each agreement includes a license issue fee, a license maintenance fee creditable towards earned royalties, milestone payments, and earned royalties based on the sale of products. An exclusive license is just what it says, an agreement to be the sole user of the licensed

technology. This type of agreement is typically used if the technology will require substantial private investment and further development to produce a marketable product.

A non-exclusive agreement allows many companies to use the technology and is typically used for technologies that apply to a broad array of use. A variation of this is to exclusively license a firm to use a technology or product in one field while the university maintains the right to license the technology to other fields. A co-exclusive license grants two companies the right to develop a technology. Finally, an option agreement allows a firm to acquire the rights to evaluate a technology for a specified period of time before committing to purchase a license. The average time required to close a licensing deal is three years, up to 9 months of that can often be spent simply arriving at a price. Carnegie Mellon has streamlined this for university based spin-offs, having a standard agreement in which the university takes a flat 5% of the equity of the spin-off company.

Universities Use Licensing Strategies

Universities can choose to pursue a large or small firm depending on the type of technology and the entity best suited to develop and market it in a product. Large firms typically license technologies that promise major innovations, substantial market size, and have a high cost and time to development. However, large firms tend to shy away from projects that require significant inventor involvement to transfer tacit knowledge (Lowe, 2002). Large firms also tend to license technologies that represent incremental improvements to their own established products. Additionally, large companies also license patents for defensive purposes, taking out exclusive licenses on patents that they have no intention of using, but doing so to prevent a potential competitor from developing a product to be marketed (Knight, 2002). Large corporate deals require smaller investments of the university's time and less money than a start-up company, but the upside potential is also usually limited. The typical returns on a license range from \$10,000 to \$50,000, often little more than enough to cover the cost of the patent.

Startup companies are more likely to license smaller scale technologies that are significant enough to form the foundation of a company. Despite the fact that most startup companies fail and are fraught with financial limitations, in some instances, a start-up company may be the most desirable licensee. Approximately three percent of patents held by universities are deemed suitable for start-up companies. However, commercialization through a start-up company may be time-consuming and financial gains are often deferred to an undetermined time in the future. Increasingly, licensing deals with startup companies include a significant equity stake that can lead to significant returns on investment (Knight, 2002). However, Meyer (2006) found in the Finnish context that although university spin-offs are important in the life sciences, most university patents were suitable for large companies. Meyer's findings suggest that large firms were the dominant driver in academic based invention utilization. The overall findings of Meyer suggest that there is a relationship between the type of invention, the type of 'field', and the size of the organization.

Jim Foley, formerly of Georgia Tech University and now Director of the Mitsubishi Electric Research Laboratory, wrote a trade article in 1996 suggesting the best means to encourage TT from universities to industry. His suggestions include numerous ideas that could contribute to theory development and academic studies:

- People, not papers, transfer technology.
- Graduate students should be encouraged to spend summers in industrial lab facilities.
- Research relationships between faculty and industrial researchers must be nurtured over time.
- Faculty and graduate students must understand the strategies of any company contracting for research.
- TT requires support from the top.

The Foley's points imply, as the literature suggests, that there are principal-agent, alliance, resource based, and transaction cost issues associated with TT. The rest of this paper attempts to integrate these four streams of research and how they apply to TT; makes suggested propositions; and, suggest areas for future development.

Four Theories to Build a TT Model

Given the complexity of the process and the number of strategy-related areas explored in university TT, there are a number of opportunities to examine major literature streams in strategy, extend them, and build theory. In doing so, studies can be developed to help universities maximize the asset value of their intellectual property and increase the value of their primary resource, the intellectual capabilities of their faculty and researchers. Figure 1, the complex relationship driving technology transfer, depicts the propositions suggested below and models the proposed relationship. We discuss the model detail after a discussion of relevant theories and propose propositions.

Agency Theory

Arrow (1962) discusses moral hazard. The separation of risk-bearing from innovation could be accomplished simply by paying the innovator a fee...as long as it is costless to monitor and evaluate the innovator's work. Unfortunately, it is not costless. Thus, the innovator must bear part of the risk. Agency theory looks at a combination of self interests and information asymmetry. Principals engage agents to perform services and both parties are utility maximizers. Hence it is likely the agent will not always act in best interests of the principal. Asymmetric information exists and there exists the possibility of exploitation. Both agents must trust the university to minimize risks.

In TT, with three parties involved, the researcher, the university, and a licensing company, there is an interesting relationship. The university acts as a central principal who brings together two agents: one who produces intellectual property and one who develops the intellectual property into a marketable product.

In a working paper for the National Bureau of Economic Research, Litan, Mitchell, and Reedy (2007) make a series of recommendations to improve the TT process. In the paper, the authors suggest that despite the fact that TTOs were created to encourage and facilitate the technology transfer process, the offices have instead become silos and gatekeepers that hinder the activity. Furthermore, the authors stress that many universities require all researchers to work with the office for IP disclosure in what they termed the “revenue maximization model” of TT (Litan et al., 2007). This view is supported by Markham et al. (2005) who found that 72% of universities prefer the licensing for cash model over other forms of licensing. This model, the authors find, discourages IP disclosure by academic researchers since it hinders the transfer process. Jensen, Thursby, and Thursby (2003) report that less than 20% of academic researchers have never reported any patent activities. The underlying problem is one of agency in that the agent has access to information that the principal lacks and would benefit from (Milgrom & Roberts, 1992). Therefore, we suggest that universities that provide greater incentives to researchers to disclose intellectual property will realize a higher rate of patent applications.

- **Proposition 1.1:** *There is a positive relationship between incentives to produce licensable research and patents applications by academic researchers.*
- **Proposition 1.2:** *There is a positive relationship between firms’ perception of previous TT from a university and likelihood of future TT attempts.*
- **Proposition 1.3:** *There is a positive relationship between a university’s positive reputation as an “above average” principal and license activities.*

Propositions 1.1 – 1.3 draw on the four principles of contract design: the Informativeness Principle; the Incentive-Intensity Principle; the Monitoring Intensity Principle; and, the Equal Compensation Principle (Milgrom & Roberts, 1992) and is illustrated in figure 1.

Alliance Literature

For any TT project to yield a successful outcome, an alliance between parties must be formed. The TT process is a three-way alliance, including the researcher, the university, and the licensing company. Entrepreneurial activity will be encouraged where appropriability is low and isolating mechanisms are high (Rummelt, 1987). Alliances exist to solve market failure problems generated by asset specificity (Chung & Singh, 2000; Gulati, 1995; Williamson, 1985). On projects in which little tacit knowledge is required and intellectual property is well protected, it is unlikely that an alliance will be formed; instead, a simple transaction will take place. However, if tacit knowledge is required to successfully use the licensed technology or if further development is needed on a core technology to create a marketable product, an ongoing alliance is required.

Universities provide an environment that allows researchers to explore new ideas and develop new technologies. Researchers provide the intellectual capacity to develop new

technologies. Companies provide capital and the infrastructure to link an idea to the market. Tying together these three parties brings ample opportunity to form an alliance. In fact, practical experience by the researcher and the literature supports the claim that universities conduct research in areas with low technology readiness levels (TRL) while firms tend to conduct research at higher levels of TRL. Implicitly, the previous statement supports the claim that university technology will tend to be more tacit since the codification necessary to reduce the knowledge to practice has not taken place. Therefore, technology that is at a lower TRL will require more direct work with the researcher or others who have had direct experience with the technology and suggests that social networks are significant (Munson & Spivey, 2006). Therefore, we suggest the following proposition:

Proposition 2.1: *There is a positive relationship between the degree of tacitness of knowledge as measured by the TRL and the likelihood to produce an alliance.*

Recently, researchers have turned their attention to the social ties and networks of affiliation with respect to technology transfer (Elayne & Peter, 2007; Morris et al., 2006; Sampson, 2007; Senge et al., 2007; Sorenson & Singh, 2007; Steiner & Hartman, 2006). Through case studies and research, investigators conclude that the structural holes (Burt, 1992) play a significant role in TT from universities to commercialization (Verspagen & Duyster, 2004). Consistent with the argument that structural holes are significant to TT, we suggest that former graduate students involved in the research projects that yield the new technology are the subject that fill the hole while the researchers' relationship with the network is indirect.

Proposition 2.2: *There is an inverse relationship between the degree of connection between the researcher and alliance formation.*

Proposition 2.3: *There is a positive relationship between firms that hire graduate students familiar with the technology and alliance formation.*

Proposition 2.4: *There is a positive relationship between university-state incentives to form spin-offs and TT startups and new venture capital the region.*

Proposition 2.5: *There is an inverse relationship between firm research and development (R&D) capital and likelihood of alliance.*

Transaction Cost Economics

Williamson (1975) explored the limits and boundaries of markets for firms and arrangements for conducting economic activity. A transaction should take place in an environment that best economizes the costs imposed by bounded rationality and opportunism. Because much of the technology developed in universities is cutting edge, it is often difficult to predict how long it will take for competitors to catch up to an innovation and how long it will take to develop a marketable product. Furthermore, as

most licensing firms are start-ups, they are cash strapped and have limited access to the capital markets before they secure a license to the technology being sought.

Proposition 3.1: *There is an inverse relationship between time to process license requests and revenue.*

Proposition 3.2: *There is an inverse relationship between length of contract negotiations and number of solicitations to license.*

Proposition 3.3: *There is a positive relationship between equity stakes and number of contracts.*

Proposition 3.4: *There is a positive relationship between cash license agreements and failure rate.*

Proposition 3.5: *There is a positive relationship between seed-funding provided by local governments and licenses.*

Resource-Based View of the Firm

University labs generally lack the human and financial resources needed to develop promising research results into commercial products. As such, they must rely on spin-off projects or licensing programs with established firms (Kettler, & Casper, 2001). Matching the appropriate intellectual property to a company that can best commercialize the technology is a critical function for any university. Universities need a TT team that understands the technical aspects of the research being developed, the business fundamentals needed to bring the technology to market, and the legal protections needed to shield the university's interests.

The resource based view (RBV) of the firm argues that firms are unique combinations of resources and capabilities (Barney, 1991; Penrose, 1995). The underlying argument of the RBV of the firm is that some firms perform better than others due to the heterogeneous nature of the infinite combinations of resources and capabilities. At the TT level, the university's likelihood of above normal returns is dependent upon the TTO's ability to match the resources developed in the lab with the capabilities of firm's to commercialize the technology. Innovation takes place at the firm level and results from the ability of the firm to apply the researcher's "ideas" to practice (McAdam et al., 2006).

Large universities may conduct research in a multitude of domains. For instance, the University of Pittsburgh conducts research in all aspects of medical development, military applications, robotics, business, and many more. The TTO employees a small number of professionals relative to the domain that they have to cover. We suggest that universities that have continuing education programs in place to broaden the understanding of the TT professionals with the TT process will outperform other universities that lack the investment in personnel education. Therefore, we suggest the following propositions:

Proposition 4.1: There is a positive relationship with TT professionals' knowledge of the "complex relationship" and license revenue.

Proposition 4.2: There is a positive relationship between TTOs with managers that possess robust backgrounds and performance.

Proposition 4.3a: There is a positive relationship between governmentally provided low-cost financing and TTA.

Proposition 4.3b: There is a positive relationship between regional incentives TTA.

An Integrated Framework

Figure 1 is an integrated framework of the complex relationship driving technology transfer. The figure depicts the four theoretical views and the affect that they have on University TT performance where University TT performance is the dependent variable.

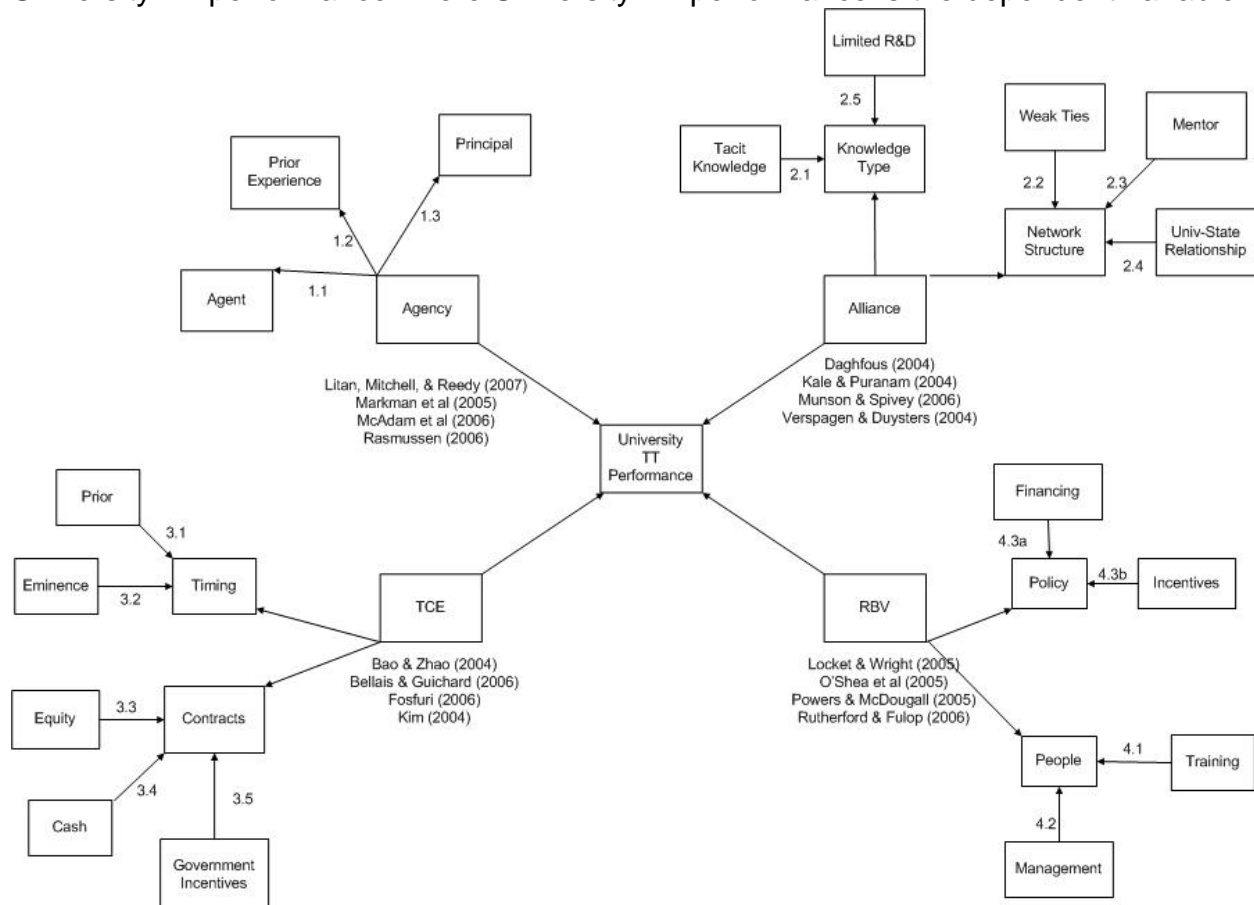


Figure 1: The complex relationship driving technology transfer

Figure 1 also includes authors associated with each area of theory. Within the model, the agency cluster is influenced by the agent, prior experience, and the principal given

by the relationship hypothesized in propositions 1.1, 1.2, and 1.3 respectively. The alliance cluster is influenced by the type of knowledge and network structure nodes as suggested by propositions 2.1 through 2.5. Likewise, the RBV and TCE clusters are thus modeled.

Discussion

In the United States, the federal government funds university research, in part, with the assumption that new technologies will spur the development of new products, create new industries, and keep the country on the cutting edge of economic possibilities. Because individuals and corporations tend to be risk-averse, the private sector underinvests in R&D, especially that which is unlikely to produce an economically-viable product in the short term. Traditionally, the Department of Defense has provided the lion's share of federal R&D dollars; however, federal agencies such as the National Institution of Health have been created to fill this gap. Universities are the primary beneficiary of these programs and create much of the technology developed via these programs.

State governments have also stepped in to play a part in high-tech development. Approximately 60% of federal research funding still comes from the Department of Defense; however, this technology is classified and cannot be marketed. In some cases, states have stepped in and offered additional sources of funding to create a market that benefits the local economy. Furthermore, the federal government has slowly backed away from funding universities and has left public education in the hands of state governments. As such, research universities have become major partners in state and regional economic development plans.

Elite research universities alone are not enough to generate spin-off and successful TT related companies. Cartright and Mayer (2002) found that metropolitan areas such as Detroit, Chicago, Houston, and St. Louis all have such institutions, but have little commercial activity associated with university-derived technology. Thus, state governments have put programs in place to recruit new high-tech firms via various incentive mechanisms to modernize their "brown field" industrial centers in an attempt to create desirable industrial centers. Further, state governments have also implemented incubators and other "seed financing" programs to help nurture new companies. Moreover, strong government/university relationships have a positive effect: Lewis (2002) found that 47% of state-sponsored incubators have a university as the lead sponsor.

Through government support of critical components and finance assistance in the early and risky stages of the development of new companies, venture capitalists are more likely to invest in new companies and participate in future rounds of financing. Numerous researchers have shown that regional success leads to increased formation rates of high-tech companies in a region. TT from local universities coupled with the assistance of state and local governments was successful in several cases of regional development, while in other cases, government incentives have shown little effect.

However, the question still exists as to whether the government is the best agent to stimulate high-tech growth. Government officials still tend to have a short-term focus and focus on election cycles. Additionally, public officials lack knowledge of the latest technologies and must rely either on instinct or the opinions of outside experts to judge the long-term potential of technologies and projects.

Areas requiring further research include micro factors such as incentives that motivate university researchers to develop appropriate technology for TT and attract entrepreneurs to a region. A nexus of individuals and organizations must be brought together to successfully nurture TT projects, including an integration of researchers, university officials, federal agencies, state and local governments, entrepreneurs, and investors.

Implications and Conclusion

A complex relationship exists between college- and university-based R&D and startup companies. Numerous players contribute to the success of new products generated via this process. The culture of institutions of higher learning and the attitudes of the researchers clearly influence the process. However, other players, in the form of entrepreneurs, corporations, and the government all influence this process. Location is an important factor, especially if the technology requires the tacit knowledge of the researcher to aid in further development. Local government can help provide a spark to attract key elements needed to form a successful startup company. Understanding how these pieces fit together and devising strategies to optimally combine these elements will not only directly benefit universities via increased licensing fees from their technology, but will also benefit the other players discussed in this paper and society as a whole. The model presented in Figure 1 suggests areas for future research both as individual clusters and as a systemic whole. Furthermore, given the nature of the system, the model lends itself to a multi-methodological research approach with a structural equation modeling measurement.

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Technology transfer, also called transfer of technology (TOT), is the process of transferring (disseminating) technology from the person or organization that owns or holds it to another person or organization. These transfers may occur between universities, businesses (of any size, ranging from small, medium, to large), governments, across geopolitical borders, both formally and informally, and both openly and secretly. Often it occurs by concerted effort to share skills, knowledge, technologies. 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 effective technology, nano-technology and hi-tech for information and communication industries in which more advanced and in-depth knowledge is required, and it is already impossible to make do with pragmatic thinking and life experience. In other words, industry requires knowledge that is produced in the universities in order to ensure economic success while decreasing the inherent risk involved in any R&D activity, and a greater ability to compete, which makes the transfer of technology vital. Therefore, universities all over the world regard the transfer of technology as an important source of financing. The complex relationship driving technology transfer: the potential opportunities missed by universities. J Lipinski, MC Minutolo, LM Crothers. *Journal of Behavioral and Applied Management* 9 (2), 115-133, 2008. A preliminary study of bully and victim behavior in old-for-grade students: Another potential hidden cost of grade retention or delayed school entry. LM Crothers, JB Schreiber, AJ Schmitt, GR Bell, J Blasik, LA Comstock, *Journal of Applied School Psychology* 26 (4), 327-338, 2010. Nowadays, global business changes at such a stunning pace, entry-level professionals barely have time to acclimate themselves to a new company, a new competitive environment, or new operational requirements. The challenges faced by young workers include lack of experience, a complex corporate world, and business education that is too theoretical [...]