Determinants of Commercial Innovation for University Technology Transfer

Kevin T. Wayne
Rivier College

Abstract

Institutions of higher education are extraordinarily dependent on external resources. Due to legal mandates and economic incentives, research universities have become increasingly active in the commercialization of university inventions. This study utilizes resource dependence theory as a framework for evaluating the influence of external resources on commercially oriented technology transfer emanating from universities. Three performance measures of university technology transfer are used including licensing revenue, licensing volume and the creation of start-up companies. Key external resources used as predictors of technology transfer performance consisted of research funding from federal and industry sources as well as state and regional venture capital munificence. The public or private status of a university is also posited as an indicator of technology transfer activity.

Federal R&D funding emerged as a consistent predictor of all three dependent measures. Federal and industry R&D, state venture capital investment and university type were found to be statistically significant indicators of start-up creation at the university level. The study concludes that resource dependence theory serves as a useful framework for studying environmental influences on commercial outputs of university technology transfer.

Keywords: innovation, university technology transfer, licensing, start-ups, resource dependence

Background

University technology transfer has become an important mechanism for economic growth in the U.S. and much of the world. The Association of University Technology Managers (AUTM) reports that 567 new products based on university or nonprofit research were introduced to the market in 2004 alone (AUTM, 2005). From 1980 to 2004, AUTM cites the creation of 4,542 spin-off companies from universities, research institutions and hospitals. Over 65% of innovations licensed by universities and institutions in 2004 were granted to small businesses for commercialization purposes (AUTM, 2005).

At the purely academic end of the spectrum, university technology transfer can mean a faculty member's presentation of basic research at a symposium or perhaps the publication of a journal article. At the commercial end, university technology transfer may involve the licensing of university inventions to an industrial firm. University faculty and students may even be directly involved with such a firm as consultants, shareholders and employees (Bozeman, 2000).

This paper focuses on commercial outputs of university technology transfer. These commercial outputs include licensing revenue collected by universities, the number of licenses granted by universities and the number of start-up companies created out of research universities. These performance measures of university technology transfer effectiveness have risen sharply over the last two decades (Business-Higher Education Forum [BHEF], 2001).

In 1980, the Bayh-Dole Act dramatically changed the incentive system for universities conducting federally supported research (Clayton-Mathews, 2001; Council on Government Relations [COGR], 1999; Department of Health & Human Services [DHHS], 2001; Godkin, 1988; Henderson & Smith, 2002). Universities were now free to collect revenue via exclusive licenses of university-owned yet federally funded technology inventions.

If government legislation such as Bayh-Dole could have such a large impact on university behavior, then perhaps there are additional external stimuli that affect university technology transfer activity (Powers, 2003). . For instance, how is university technology transfer performance influenced by levels of external research funding or the availability of investment capital?

Research universities are extraordinarily dependent on external resources (Dill, 1990; Slaughter & Leslie, 1997). Pfeffer and Salancik (1978) posit that organizations are by and large driven by forces in their external environments, and thus are not completely autonomous, self-directed entities. Pfeffer and Salancik go further in stating that organizations will seek to stabilize their interactions with external actors by establishing alternate relationships or dependencies.

Resource dependence theory (Pfeffer & Salancik, 1978), institutional theory (Oliver, 1991), agency theory (Arrow, 1985), real options theory (Trigeorgis, 1996), transaction costs theory (Williamson, 1985), revenue theory of costs (Bowen, 1980) and resource-based view frameworks (Barney, 1991; Penrose, 1959/1995) have been the theoretical bases for past studies of university technology transfer. Much of the research performed to date on university technology transfer has been centered on the internal attributes of organizations. However, resource dependence theory has not been fully exploited as a means to understand and predict university technology transfer performance. While conscious of the notion that no organization exists in a vacuum, this study focuses on the relationships of external stimuli on technology transfer performance using resource dependence theory as a framework.

Literature Review

The most galvanizing event affecting university technology transfer was the Bayh-Dole Act of 1980 (US Patent and Trademark Reform of 1980). According to AUTM (2002), research universities spent over $25 billion of federal funds on basic research in 2000. However, revenue paid to universities resulting from licensing activities and start-up equity was still relatively low compared to gross expenditures on research. AUTM reports aggregate licensing income of nearly $1.1 billion in 2000 from reporting institutions.

Invention disclosures and patent activity has also grown tremendously since 1980. Colyvas et al. (2002) reports a doubling of patents granted to U.S. universities in both of the five-year periods 1979-1984 and 1984-1989. Spin-offs, perhaps the most visible form of university technology transfer, have proved quite lucrative for the Massachusetts Institute of Technology (MIT). MIT has helped create nearly 4,000 high tech companies employing over one million people with annual revenue of $232 billion (Rogers, et al., 1999). Spin-offs are often found to be geographically dense, as is the case near MIT, Stanford and the University of Texas at Austin. Proximity to top-tier universities has been attributed to the success of industrial high technology clusters such as California's Silicon Valley and the Route 128 area near Boston (Freel, 2000; Rogers, et al., 1999).

Rogers et al. (1999) found factors contributing to the creation of these 'technopolises' were abundant venture capital, access to innovation and an overall entrepreneurial climate. In further testament to geographic importance, Varga (2000) described the necessity of a 'critical mass of agglomeration' being attained in order to facilitate significant local economic effects of academic research spending. Indeed, AUTM (2002) reports that 80% of start-ups resulting from university inventions are located in the home state of the originating university.

While a clear division of labor exists between university and industry (Rosenberg & Nelson, 1994), this specialization exploits the relative strengths of academe and industry. Universities are not particularly adept at downstream activities such as production (i.e., scale up), marketing and distribution of commercial products. These functions are much better suited for private industry to accomplish. Furthermore, considerable risk-taking and investment are often required in later stages of technology development (Eisenberg, 1996).

Faculty, especially those referred to as faculty entrepreneurs, have an increased chance of seeing their ideas turned into real-world applications as a result of university-industry collaborations. Additionally, faculty members are often allowed to participate in commercial ventures via equity stakes or by receiving a portion of the royalties from university licenses (Feldman et al., 2002; Okada, 1999). Not coincidentally, the Bayh-Dole legislation contains language stipulating that inventors must be compensated for revenue generating licenses (COGR, 1999).

University technology transfer to industry gives the university some leverage in the financing of research. The university may be less dependent on the federal government for future funding. A more diverse funding pool provides the university with a cushion against major cutbacks from government, industry or foundation sources. This type of 'revenue diversification' (Froelich, 1999) is an example how a university can reduce its dependence on external stakeholders.

Arora and Gambardella (1994), in their study of external linkages in the biotechnology industry, conjectured that universities function not so much as innovators but as important sources of scientific information and capabilities. The act of commercial innovation is left up to collaborating industrial firms that may utilize university know-how.

Smith (2000) argued that government policies should be continually reviewed in light of technology 'transition failures' due to infrastructural, institutional and investment climates. Public stimulus, as was the case with the Bayh-Dole Act of 1980, may be required to spur technology and knowledge transfer.

Spencer (2001) found that research done by university researchers led to subsequent work by corporate researchers. In a study of flat panel display technologies, it was found that university research in both the U.S. and Japan is often confined to the home country. Thus, university research contributed more to a country's national innovation system than to the world's innovation system. Seitzer (1999) points out that technology transfer will likely follow market rules in the future due to trends in globalization and increased pressures to do more with less resources (i.e., become more productive).

Freel (2000) demonstrated that firms described as innovators were more inclined to have formal relations with research universities versus firms characterized as non-innovators. In addition, Spencer (2001) stated that university research was cited less often than industrial research in writings by industrial scientists. Small firms in particular can benefit from university relationships due to the limited scope and scale of small firms' in-house research capabilities. University relationships are included in the regimen of important external linkages for small firms. These linkages also include suppliers, customers, government agencies, trade groups and competitors (Freel, 2000).

Feldman et al. (2002) surveyed leading U.S. research universities regarding their use of equity as a technology transfer mechanism. Equity-based technology transfer has recently become a popular method for universities to generate income from industrial firms (licensees). Equity-based transfer mechanisms involve the university receiving an equity stake (through stock ownership) in the firm that licenses technology from the university.

Resource Dependence

Resource dependence theory detracts from economics-based theories (i.e., transaction-cost theory) due to its focus on uncertainty reduction and power versus an emphasis on efficiency (Pfeffer, 1997). It distances itself from network theories as well by emphasizing the distinct nature of an organization apart from other members of consortia or networks. However, the success and survival of organizations often depend on the patterns of connections, or interdependencies with other organizations (Pfeffer & Salancik, 1978).

Organizations are constrained by interdependencies with external actors that they interact with (Pfeffer, 1982). To reduce uncertainties presented by externalities, organizations will attempt to become less dependent on them by stabilizing these interactions via the establishment of alternate relationships or dependencies. The theory states that firms attempt to dilute the impact of external actors wielding significant power over them in particular resource relationships.

Flynn (1993), in his analysis of sponsorship regimes and their impact on small business survival, claimed a small firm's survival may be threatened by an over-dependence on external sponsors. Even in cases of 'benevolent' sponsorship, small firms must be able to successfully adapt to a life that one day will not include sponsorship. Small organizations are particularly vulnerable due to their lack of diversification. Steensma, Marino, Weaver and Dickson (2000) found resource dependence helpful in explaining how alliance formation is employed in cultures that avoid uncertainty and that also value cooperation.

Froelich (1999) investigated evolving resource dependence in non-profit organizations. Evidence of shifting dependence was found with non-profits relying on varying degrees of support from private contributions, government funding and commercial activities.

Dill (1990) looked at university/industry collaborations through the lenses of population ecology, resource dependence, marketing and process perspectives. Dill points out how research activities of U.S. universities are "free from direct national control" (p.124). Dill also describes the seeking of financial resources by U.S. universities as an entrepreneurial activity. Furthermore, Dill contends that universities undergo vertical integration by establishing licensing offices and joint ventures. However, he refers to these mechanisms in the context of a population ecology perspective. It is argued in this study that vertical integration activities are active adaptations conducted by individual universities. Therefore, resource dependence theory may be a more appropriate framework for such declarations.

Both public and private research universities in the U.S. are heavily dependent on federal grant money in order to conduct basic research. State support for higher education has been declining relative to other state budget items (Fairchilds, 2001; Powers, 2000; Slaughter & Leslie, 1997). A resource dependence perspective would argue that public institutions of higher education, faced with unstable and declining state support, would reduce this resource uncertainty by seeking more controllable resource options.

Meanwhile, federal agencies (grantors) are allowing less autonomy in the use of federal funding to universities (Slaughter & Leslie, 1997). Discretion over a resource is a source of power (Pfeffer & Salancik, 1978). The guidelines and regulations stipulated in some grants may be critical determinants of university research behavior.

Changes in higher education policies and national research edicts may be affecting the resource dependence make-up of universities (Slaughter & Leslie, 1997). One such change is the sharp increase in private industry funding of university research in recent years. Industry-based research and development are ideally suited to assist universities which are traditionally immersed in basic, less applied science. Assistance from industry can improve the commercialization prospects of inventions due to industry's superior product development and marketing skills. Thus, universities have a dependence on the industrial sector for product development and market accessibility.

Slaughter and Leslie (1997) attributed much of the internal behavior of academia as a reaction to the acts of external contributors. Anderson (2001) points to fundamental changes in academy-industry relations in her critique of *Academic Capitalism* (Slaughter & Leslie, 1997), *Capitalizing Knowledge* (Etzkowitz, Webster & Healey, 1998) and Tudiver's *Universities for Sale*. Anderson points out that there are many political and economic pressures on universities to commercialize basic research. These pressures may include a 'push' for licensing revenue within the university or a 'pull' from outside the university. External pressures include state and local economic development as well as commercial market demand (Dill, 1990).

Performance Metrics and Predictor Variables

Licensing revenue, number of licenses granted and number of start-ups created from university technology serve as dependent measures for this study. These variables represent credible, commercial performance measures of successful university technology transfer. All three of these activities are posited as mechanisms of revenue diversification for universities. Together, it is argued that these variables may also function as constructs of a more robust and representative outcome variable of commercially oriented technology transfer.

Noticeably absent from these commercial measures are patent awards, patent applications and invention disclosures. Focused research efforts on these invention-related measures are essential but not applicable to this study. The technology transfer performance metrics being utilized in this study are more downstream (i.e., closer to the market) than invention and patenting activities. However, invention disclosures and patent awards are antecedents to licensing activity.

The independent variables used in this study include the level of external research funding, geographic munificence of venture capital and the type of university (i.e., public or private). External research funding is measured and categorized into two different inputs including federal government funding and private industry funding. A model is provided in Exhibit 1 of the Appendix to visually demonstrate the relationships being examined in this study.

Sample

Research universities make up 6.6% (n = 261) of the 3,941 institutions of higher education located in the U.S. (Carnegie Foundation, 2000). This study's initial sample of 109 research universities is comprised of those U.S. research universities participating in each of the four AUTM Annual Surveys, Fiscal Years 1997 through 2000. The sample accounts for 49% of AUTM's FY 2000 population of 221 research universities.

As a result of running scatterplots, histograms and rankings for every variable and relationship, seven universities were excluded from the sample due to outlier values. Descriptive statistics for the finalized sample of 102 universities are summarized in Exhibit 2 of the Appendix. The revised sample includes 28 private (27.5%) and 74 public

(72.5%) universities, a mix that compares closely with past studies of the same population (Feldman et al., 2002; Powers, 2003; Trune & Goslin, 1998).

Correlations

In an effort to ascertain the relatedness of variables to each other, bivariate correlations were run for all independent and dependent variables prior to regression analysis. Pearson correlation coefficients outside of the -.70 to .70 range may indicate problems with collinearity amongst variables. The correlation matrix is provided in Exhibit 3 of the Appendix.

The correlation matrix reveals one relationship with a Pearson coefficient above .70. The independent variable federal R&D funding and the dependent variable number of licenses combine for a Pearson correlation of .81 that is statistically significant ($p < .01$). No coefficients produced by pairs of independent variables indicated any collinearity problems. However a coefficient of .69 ($p < .01$) from two dependent variables, start-ups and number of licenses, indicates a fairly strong degree of relatedness between these two outcome measures. This correlation is not unexpected given that a university-granted license is often a condition for initiating a university start-up (AUTM, 2002).

Research Question and Hypotheses

To reiterate the focus of this study, the following research question is presented: To what extent does select external stimuli influence commercial indicators of university technology transfer performance? Fifteen hypotheses are presented next in Table 1 with the results of regression analysis, including corresponding Beta coefficients and level of statistical significance, if applicable.

Table 1. Results of Hypothesis Testing

Hypothesis	**Beta**	**Supported**
H_a1a: The amount of federal R&D funding received by a university is positively related to the licensing revenue received by the university.	.567***	Yes
H_a1b: The amount of federal R&D funding received by a university is positively related to the number of licenses granted by the university.	.774***	Yes
H_a1c: The amount of federal R&D funding received by a university is positively related to the number of start-ups created out of the university.	.552***	Yes
H_a2a: The amount of industry R&D funding received by a university is positively related to the licensing revenue received by the university.	-.021	No
H_a2b: The amount of industry R&D funding received by a university is positively related to the number of licenses granted by the university.	.048	NO

H_a2c The amount of industry R&D funding received by a university is positively related to the number of start-ups created out of the university.	.187*	Yes
H_a3a: Venture capital munificence, at the state level, is positively related to the licensing revenue received by a university.	-.047	N0
H_a3b: Venture capital munificence, at the state level, is positively related to the number of licenses granted by a university.	.058	No
H_a3c: Venture capital munificence, at the state level, is positively related to the number of start-ups created out of a university.	.261**	Yes
H_a4a: Venture capital munificence, at the regional level, is positively related to the licensing revenue received by a university.	.108	No
H_a4b: Venture capital munificence, at the regional level, is positively related to the number of licenses granted by a university.	-.041	No
H_a4c: Venture capital munificence, at the regional level, is positively related to the number of start-ups created out of a university.	-.026	No
H_a5a: Public universities will experience more licensing revenue than will private universities.	.053	No
H_a5b: Public universities will grant more licenses than will private universities.	-.058	No
H_a5c: Public universities will create more start-ups than will private universities.	-.164*	Yes

*p < .05; **p < .01; ***p < .001

The results of hypotheses testing provide statistically significant support for six of the fifteen predicted relationships. A summary of the three regression models utilized, with each model representing a dependent variable measure of technology transfer performance, is provided in Table 2. Individual model outputs, including ANOVA statistics, are provided in the Appendix (Exhibits 4, 5, and 6).

Table 2: Summary of Multiple Regression Models

Independent Variables and Standardized Coefficients (Beta)	**Model 1: Licensing Revenue**	**Model 2: Number of Licenses**	**Model 3: Start-up Companies**
Federal R&D Funding	.567***	.774***	.552***
Industry R&D Funding	-.021	.048	.187*

State Level VC	-.047	.058	.261**
Regional Level VC	.108	-.041	-.026
University Type	.053	-.058	-.164*
F-Value	9.13***	36.53***	25.03***
Adjusted R^2	.287***	.638***	.543***

*p < .05; **p < .01; ***p < .001

Discussion of Results

In Model 1, an adjusted R^2 of .29 indicated the model explained 29% of the variance for the dependent variable licensing revenue. The only explanatory variable that was statistically significant in the prediction of licensing revenue was federal R&D funding, with a Beta of .57 at a significance level of $p < .001$.

Next, regression Model 2 used number of licenses as the dependent variable. This model exhibited an adjusted R^2 of .64 indicating that the model explained 64% of the variance in the number of licenses generated. Model 2 also showed federal R&D funding as the lone statistically significant predictor of the outcome variable. The Beta for federal funding was a strong .77 and was significant at the level of $p < .001$. In recalling the high Pearson correlation between federal R&D funding and number of licenses presented earlier, this finding is not surprising.

The third regression analysis, Model 3, attempted to predict the number of start-ups created at research universities. This model produced an adjusted R^2 of .54, explaining 54% of the variance in start-ups reported. Whereas Models 1 and 2 revealed federal R&D funding as the only statistically significant predictor of the dependent variables, Model 3 yielded four explanatory variables that were statistically significant. These findings hint at the multi-factorial and complex nature of start-up creation.

Federal R&D expenditures stood out as the most consistent predictor of technology transfer performance. A fundamental precept of resource dependence theory is that organizations will actively alter their behavior as a result of real or perceived changes in environmental conditions. Legislation changed the rules of the game and prompted universities to become more commercially active. The predictive success of federal funding on technology transfer outcomes is indicative of how critical the procurement of an external resource is to the success of university technology transfer.

Given the results of federal funding as a predictor, U.S. research universities appear heavily dependent on agencies of the federal government. However, one can argue that federal agencies (grantors) are dependent on research universities to fulfill basic research missions with federal funds. Assuming the U.S. Government has a taxpayer mandate to improve societal conditions, research universities may be a means to accomplish this objective via commercialization of research.

Federal research funding is critical to sustaining a university's research mission. Discretion over the use of funds usually depends on the type of grant or research program, but suffice it to say that universities have more autonomy and discretion with federal funds than with industry expenditures. Also, the large and highly significant effects shown by federal funding in this study may be indicative of a lack of alternative sources of funding for universities.

Interestingly, licensing revenue and number of licenses seem highly dependent on federal funding since it was the lone significant predictor variable for both licensing outcomes. By itself, federal funding explained 64% of the variance for number of licenses. The predictive effect of federal R&D on licensing revenue was highly significant but helped explain only 29% of the variance of licensing revenue. This finding makes sense in light of the large fluctuations and 'hit or miss' nature of licensing revenue.

The results from hypothesis sets H1a and H1b provide support for positive relationships of federal funding with licensing revenue and number of licenses reported by Powers (2003). However, Powers' results were of considerably less magnitude (Betas = .19 and .16, respectively) and not statistically significant. The results for predicting start-up creation confirm findings from Powers (2000) that were less positive but statistically significant (Beta = .28, $p < .05$) in comparison to the current study.

Industry support of university research, while still considerably less than federal contributions, is growing at a faster rate than government funding (Bozeman, 2000; Lee, 1996; NSF, 2002). Growth in funding from industry may signify a shift of dependency away from government sources and towards industry. However, industry R&D funding was not a significant indicator of licensing revenue or number of licenses. This may be due to the relative superiority of federal funding in terms of size and past funding patterns. Also, there is some stigma and suspicion attached to the association of academic research with private industry. Lee (1996) reported research university faculty as not approving of equity deals and start-up support from universities.

Industry R&D was found to be a positive and statistically significant indicator of start-ups created. This finding may be due to the entrepreneurial nature of individual universities. Perhaps a university that excels in industry partnerships is more savvy and/or aggressive when considering the downstream commercial activity of start-up creation. Certainly, MIT is an example of an institution that aggressively spins off companies and also ranks very high in securing industry R&D funds. In contrast, Duke University ranks as the sample's leader in industry R&D expenditures but is not a strong performer in start-up creation.

Additional enablers of start-up activity may include university policies, the entrepreneurial nature of faculty, local availability of surrogate entrepreneurs (Radosevich, 1995), existence of incubators and the credibility of university licensing offices. Nevertheless, the level of industry R&D intensity at a university may be indicative of the university's degree of market orientation, which in turn results in more start-up activity. Also, substantial amounts of industry R&D expenditures are for contract research and may not necessarily result in commercial output measures. This study did not examine characteristics of industrial licensees (e.g., types of firms or industries) which may be relevant to start-up formation.

The results in H2a and H2b are similar to the slight and insignificant effects found by Powers (2003). The results for industry funding as predictor of start-ups are consistent with and supportive of Powers (2000) earlier findings (Beta = .20, $p < .05$).

State venture capital munificence was not found to be a statistically significant predictor of either licensing revenue or number of licenses. However, this explanatory variable was a statistically significant indicator of number of start-ups (Beta = .26, $p < .01$). These results do not support findings from Powers (2003) that revealed state level VC munificence as a negative predictor of licensing revenue and number of licenses. The results for start-up companies are supportive of Powers (2000) although the current results show a stronger and more significant relationship.

Different time periods may explain some of the variability between the work of Powers (2000; 2003) and the results of the current study. Notably, data used by Powers for state VC munificence reflects the period 1993 – 1995. The current study utilizes more recent data including the years 1997 – 2001. The latter period represents an extraordinary boom in VC investment in the U.S. Also, examination of VC data used by Powers (2000) reveals zero values for several states (n = 13). The current study likely benefits from a more robust data set. This is perhaps due to improved data collection by the primary data provider (PriceWaterhouseCoopers).

Regional venture capital failed to show any statistically significant relationship in any of the regression models. Given the void of past empirical research regarding the influence of regional capital availability on university technology transfer performance, there is little to compare the current results with. Regression on the preliminary sample data revealed regional VC munificence as a positive and very significant predictor of licensing revenue (Beta = .45, $p < .001$). This was a sharp change in the statistical result produced using the qualified study sample (Beta = .11, not significant). Note that the outlier institutions included Stanford, University of California, Columbia and MIT. These universities are top performers in terms of licensing revenue and are located in regions of extraordinary VC activity (e.g., California, NY Metro and New England regions). This indicates a link with technology transfer performance and regional VC, albeit due to the performance of super-achieving institutions.

This study does not account for all external environmental influences. For instance, the hypotheses utilizing venture capital activity do not account for effects of social capital and networks of venture capital organizations (Shane & Stuart, 2002; Sorenson & Stuart, 2001).

State level VC investment did not result in strong nor significant effects for predicting licensing revenue and number of licenses. However, state VC was recorded as a positive and statistically significant indicator of start-up companies. These findings are understandable given that licensing activity is broadly based across new ventures and large companies. For instance, a university may prefer licensing technology to a larger company with substantial market clout in order to maximize royalties. Levels of VC munificence were not seen as critical determinants of overall licensing activity.

For start-up creation, however, state VC levels would be expected to have an impact as the results have indicated. While state borders are relatively permeable to capital flows, state VC measures represent a localized environmental resource for entrepreneurial activity. According to the AUTM FY 2000 Survey, 80% of the reported start-ups in 2000 were located in the home state of the reporting institution (AUTM, 2002). The majority of the reported start-ups originated from university invention. These facts highlight the importance of close proximity with regard to VC investment in new companies. The current study's findings are supportive of work by Sorenson and Stuart (2001) that showed the propensity for investment by a VC firm is largely reduced as the geographic distance from a new venture increases.

The current study appears to be a first attempt at gauging the effect of regional VC on licensing revenue, number of licenses and start-ups using a nationwide sample of U.S. research universities. Regional VC munificence serves as a resource measure that is broader than the majority of state VC figures and is not generally restricted to state borders. VC investment at a multi-state level may highlight relationships pertinent to universities and their roles in regional economic development. For instance, do universities in states with minimal VC outlays, such as Maine, benefit with regards to technology transfer performance by being near states with high VC intensity like Massachusetts? Questions like this are not fully answered by the current study. However, none of the study's models yielded statistically significant effects for regional VC munificence.

The availability of investment capital has long been considered a critical resource for technology-intensive enterprises (Schoonhoven & Eisenhardt, 1993). Indeed, areas with scarce venture capital resources have been found to be disadvantaged with regard to forming academic spin-offs (Radosevich, 1995; Roberts & Malone, 1996; Rogers et al., 1999).

In predicting number of start-ups, university type emerged as a positive and statistically significant indicator with a Beta coefficient of -.16 ($p < .05$). Since public universities were coded with a 0 (private institutions = 1), a negative coefficient indicated that public universities had more of an effect on start-ups than did private universities. Thus, the standardized coefficient result is in the predicted direction.

The results for university type are similar to Powers (2003) with respect to weak directional effects and insignificant findings for licensing revenue and number of licenses. Also, Powers (2000) reported a negligible (Beta = .01) and insignificant effect for private universities as an indicator of start-up creation. However, Powers did find that private universities were positive and significant indicators of licensee companies that underwent initial public offerings (IPOs). The IPO characteristic was not utilized as a variable in this study due to the inconsistent nature of IPO activity in U.S. equity markets.

In contrast to Powers (2000), the current study finds significant support for the prediction that publics, not privates, are more likely to induce start-ups. This result is aligned with Feldman et al. (2002) findings that public universities were more inclined to engage in equity-linked licenses than their private counterparts.

Public universities may be trying to overcome the uncertainties created as a result of reduced state funding for higher education. Some state universities are attempting to become less dependent on state government budgets. For instance, many state universities are limited to the extent they can raise tuition rates. Private institutions are not nearly as dependent on state funds and are not restricted by legislated tuition constraints. It is understandable to hear of public universities wanting to cut dependency ties with their state governments. For instance, the privatization of a public university would be a most compelling testament of resource dependence theory.

Limitations of Study

Concern was raised earlier regarding the possibility of a reciprocal nature between the federal R&D expenditure variable and the study's outcome variables. More research is required to distinguish any bi-directional effects of funding and technology transfer output measures. For example, could funding be influenced by a university's past performance regarding licensing or start-up activity? A form of reputational capital may have an effect on an institution's ability to procure resources such as federal grants.

From a theoretical perspective, the dimensions of competition within the resource dependency framework are not fully addressed in this study. Research universities are competing for a finite supply of research grants, as well as a finite supply of top students and faculty. Start-up companies spawned by universities are also competing for investment capital in order to grow. Although the research includes measures of critical external sources of financial capital, university characteristics that may make institutions more successful at acquiring these resources are not examined. These characteristics include faculty quality, licensing office size and experience, the presence of university incubators, university size, reputation and stated mission.

Implications for Practice

Professional societies such as AUTM, the Licensing Executives Society and the Association of American Universities are keenly interested in the growth and enablers of university technology transfer. Also, it is hoped that this study's results are used in open dialogue amongst the different stakeholders of university technology transfer. Public policy makers and university administrators must not only communicate with each other but also include practitioners such as venture capitalists, licensing professionals, faculty researchers, industry representatives and entrepreneurs in debates concerning the commercialization of university technology transfer.

Implications for Future Research

Future research in this domain should be cognizant of outlier cases. The statistical effects of 'super achiever' universities should be diligently examined. Research designs that incorporate or define best practices for university technology transfer may dramatically aid in understanding the domain. Research combining the study of internal processes with external influences is also recommended.

Caution should be exercised when attempting research using multi-theoretical frameworks. While the phenomena of university technology transfer does provide a rich set of circumstances to study, theoretical overlap presents both problems and opportunities for identifying and constructing appropriate variables. For instance, Powers (2003) considered federal and industry R&D expenditures to be within the realm of a resource-based view (i.e., internal to the university). The current study considered these research expenditures as external resources and more appropriately falling under a resource dependence framework. However, internal organizational capabilities likely have an impact on winning competitive grants.

In general, further research is encouraged due to the changing roles and expectations regarding American institutions of higher education within an increasingly competitive global economy. Questions as to how political dynamics, both inside and outside the university, influence technology transfer are worthy of study. Lastly, research frameworks that utilize quantitative as well as qualitative methodologies are recommended.

Appendix

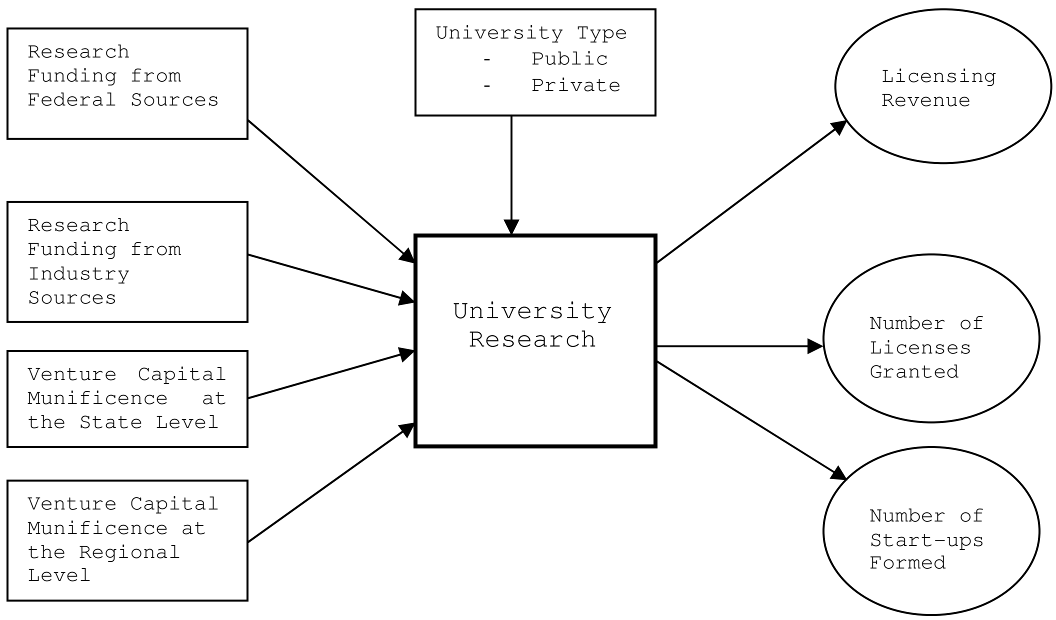

Exhibit 1. Hypothesized Model: External Influences On University Technology Transfer.

Exhibit 2: Means, Ranges and Standard Deviations

Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Federal R&D Funding	102	$4,520,750	$417,794,305	$98,192,029	$83,987,153
Industry R&D Funding	102	$72,005	$86,484,778	$15,322,884	$15,285,113
State Level VC	102	$2,440,000	$19,887,780,000	$1,339,566,667	$2,860,013,853
Regional Level VC	102	$66,420,000	$5,339,880,000	$2,548,394,118	$1,368,965,979
University Type	102	0	1	.27	.448
Licensing Revenue	102	$500	$23,015,784	$3,239,258	$5,035,241
Number of Licenses	102	.50	101.00	21.51	23.81
Start-up Companies	102	.00	13.00	2.03	2.24
Valid N (listwise)	102				

Exhibit 3: Correlation Matrix

Correlations

		Federal R&D Funding	Industry R&D Funding	State Level VC	Regional Level VC	University Type	Licensing Revenue	Number of Licenses	Start-up Companies
Federal R&D Funding	Pearson Corr.	1	.574**	.244**	.007	.181*	.554**	.805**	.694**
	Sig. (1-tailed)	.	.000	.007	.470	.034	.000	.000	.000
	N	102	102	102	102	102	102	102	102
Industry R&D Funding	Pearson Corr.	.574**	1	.019	.068	-.010	.310**	.491**	.509**
	Sig. (1-tailed)	.000	.	.426	.247	.460	.001	.000	.000
	N	102	102	102	102	102	102	102	102
State Level VC	Pearson Corr.	.244**	.019	1	.179*	.319**	.127	.222*	.343**
	Sig. (1-tailed)	.007	.426	.	.036	.001	.102	.013	.000
	N	102	102	102	102	102	102	102	102
Regional Level VC	Pearson Corr.	.007	.068	.179*	1	.186*	.112	-.033	.007
	Sig. (1-tailed)	.470	.247	.036	.	.031	.131	.372	.473
	N	102	102	102	102	102	102	102	102
University Type	Pearson Corr.	.181*	-.010	.319**	.186*	1	.160	.093	.012
	Sig. (1-tailed)	.034	.460	.001	.031	.	.054	.177	.450
	N	102	102	102	102	102	102	102	102
Licensing Revenue	Pearson Corr.	.554**	.310**	.127	.112	.160	1	.507**	.492**
	Sig. (1-tailed)	.000	.001	.102	.131	.054	.	.000	.000
	N	102	102	102	102	102	102	102	102
Number of Licenses	Pearson Corr.	.805**	.491**	.222*	-.033	.093	.507**	1	.690**
	Sig. (1-tailed)	.000	.000	.013	.372	.177	.000	.	.000
	N	102	102	102	102	102	102	102	102
Start-up Companies	Pearson Corr.	.694**	.509**	.343**	.007	.012	.492**	.690**	1
	Sig. (1-tailed)	.000	.000	.000	.473	.450	.000	.000	.
	N	102	102	102	102	102	102	102	102

**. Correlation is significant at the 0.01 level (1-tailed).

*. Correlation is significant at the 0.05 level (1-tailed).

Exhibit 4: Regression Results, Model 1: Licensing Revenue

Model 1 Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
1	.568[a]	.322	.287	$4,251,551	.322	9.133	5	96	.000

a. Predictors: (Constant), University Type, Industry R&D Funding, Regional Level VC, State Level VC, Federal R&D Funding. b. Dependent Variable: Licensing Revenue

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	825452670312728	5	165090534062546	9.133	.000[a]
	Residual	1735266104125783	96	18075688584644		
	Total	2560718774438511	101			

a. Predictors: (Constant), University Type, Industry R&D Funding, Regional Level VC, State Level VC, Federal R&D Funding. b. Dependent Variable: Licensing Revenue

Coefficients[a]

		Unstandardized Coefficients		Std. Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
1	(Constant)	-1057891	1026525		-1.031	.305		
	Federal R&D Funding	3.402E-02	.007	.567	5.204	.000	.594	1.685
	Industry R&D Funding	-7.020E-03	.035	-.021	-.203	.840	.638	1.568
	State Level VC	-8.322E-05	.000	-.047	-.513	.609	.831	1.204
	Regional Level VC	3.976E-04	.000	.108	1.242	.217	.932	1.073
	University Type	590782	1019549	.053	.579	.564	.856	1.168

a. Dependent Variable: Licensing Revenue

Exhibit 5: Regression Results, Model 2: Number of Licenses

Model 2 Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
2	.810[a]	.655	.638	14.333	.655	36.528	5	96	.000

a. Predictors: (Constant), University Type, Industry R&D Funding, Regional Level VC, State Level VC, Federal R&D Funding

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
2	Regression	37520	5	7504	36.528	.000 [a]
	Residual	19721	96	205		
	Total	57241	101			

a. Predictors: (Constant), University Type, Industry Funding, Regional VC, State VC, Federal Funding. b. Dependent Variable: No. of Licenses

Coefficients[a]

		Unstandardized Coefficients		Std. Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
2	(Constant)	.846	3.461		.244	.807		
	Federal R&D Funding	2.193E-07	.000	.774	9.951	.000	.594	1.685
	Industry R&D Funding	7.537E-08	.000	.048	.645	.520	.638	1.568
	State Level VC	4.797E-10	.000	.058	.877	.383	.831	1.204
	Regional Level VC	-7.206E-10	.000	-.041	-.668	.506	.932	1.073
	University Type	-3.043	3.437	-.057	-.885	.378	.856	1.168

a. Dependent Variable: Number of Licenses

Exhibit 6: Regression Results, Model 3: Number of Start-ups

Model 3 Summary

					Change Statistics				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	R Square Change	F Change	df1	df2	Sig. F Change
3	.752[a]	.566	.543	1.515	.566	25.031	5	96	.000

a. Predictors: (Constant), University Type, Industry R&D Funding, Regional Level VC, State Level VC, Federal R&D Funding

ANOVA [b]

Model		Sum of Squares	df	Mean Square	F	Sig.
3	Regression	287	5	57.42	25.031	.000 [a]
	Residual	220	96	2.29		
	Total	507	101			

a. Predictors: (Constant), University Type, Industry R&D Funding, Regional Level VC, State Level VC, Federal R&D Funding

b. Dependent Variable: Start-up Companies

Coefficients[a]

		Unstandardized Coefficients		Std. Coefficients			Collinearity Statistics	
Model		B	Std. Error	Beta	t	Sig.	Tolerance	VIF
3	(Constant)	.219	.366		.599	.550		
	Federal R&D Funding	1.474E-08	.000	.552	6.328	.000	.594	1.685
	Industry R&D Funding	2.746E-08	.000	.187	2.224	.028	.638	1.568
	State Level VC	2.049E-10	.000	.261	3.544	.001	.831	1.204
	Regional Level VC	-4.334E-11	.000	-.026	-.380	.705	.932	1.073
	University Type	-.820	.363	-.164	-2.26	.026	.856	1.168

a. Dependent Variable: Start-up Companies

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