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ABSTRACT

The purpose of this study was to investigate the effects of critical resource flows on technology transfer activity. The investigation focused on the impact on a university's licensing orientation of four sources of research and development (R&D) revenues: federal, state, industry, and institutional. By licensing orientation is meant the number of licenses with start-ups and small firms and licenses with large firms. The sample consisted of 104 doctoral extensive and intensive institutions for which information was available on each of the variables of interest. Data were collected from surveys and from the National Science Foundations annual reports on academic R&D. Federal R&D was a significant positive predictor of performance in both models. As was consistent with other research, federal R&D was predictive of university start-up activity. Federal dollars have declined as a share of R&D funding but many federal agencies are less likely to impose cost sharing requirements on grantees. Overall, universities seemed likely to devote institutional resources to potentially high-risk, but high-return, activities as opposed to working with large companies. Since institutional R&D is the fastest growing source of academic R&D and the one on which an institution can exercise the most control, it may be the best barometer of entrepreneurial orientation of any of the R&D funding areas. State R&D funding is more likely to be associated with large company licensing. The implications of these findings for higher education policy and practice are discussed. (Contains 52 references.) (SLD)

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# Critical Resource Effects on America's Universities: What's Behind the Growing Entrepreneurial Orientation?

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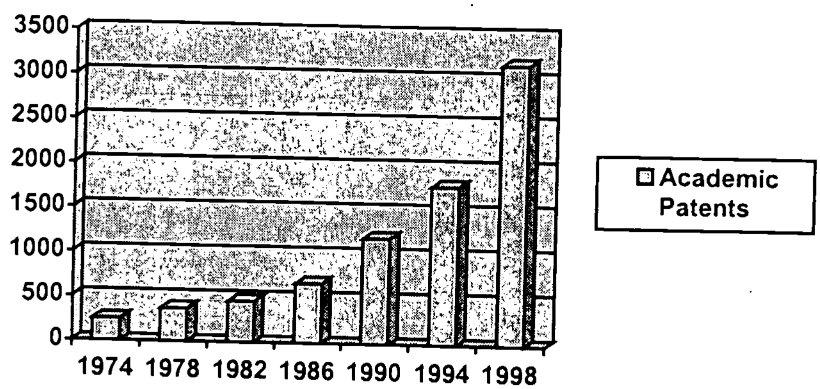
## Introduction

In the past decade, American research universities have substantially expanded their R&D mission to include much more active involvement with the commercial sector. While in earlier periods of their history, R&D was pursued largely from a disinterested inquiry perspective (Bozeman, 2000), today, academic research is increasingly pursued for its commercial potential and value as intellectual property that can be exploited for financial gain (Slaughter & Leslie, 1997). Much has been written in both the scholarly and popular press about this growing entrepreneurial phenomenon, some from the perspective that it is a legitimate and appropriate aim given the needs for national and regional economic development (Etzkowitz & Leydesdorff, 2000; Levy, 1998; Roberts & Malone, 1996) and others from the viewpoint that it undermines the very core of what has made our nation a world technological leader, academic research pursued for its own sake leading to break through advances in ways never imagined (Campbell & Slaughter, 1999; Fairweather, 1988; Press & Washburn, 2000).

Regardless of one's view of the phenomenon, it appears certain that this new course, or what Etzkowitz (1998) calls the second academic revolution, is likely to continue given two fundamental forces at work. First, like never before, economic development has become a legitimate purpose of higher education, traceable as a particularly important mission to 1980 and the passage of the Bayh-Dole Act. Following the oil embargo period in the 1970s and the subsequent realization that America was no longer the primary player on the world economic stage, attributable in large part to the high profile failures of the automotive industry, Congress moved rapidly to reassert American dominance. Among other related concerns, Congress was worried that the U.S. R&D enterprise was in need of attention. Specifically, academic patenting of inventions was anemic, due in large part to the cumbersome and complicated process by which an institution might obtain the rights to an invention funded from federal sources (Etzkowitz & Stevens, 1998). The patenting of inventions, it was believed, was important for getting more good ideas off of the lab table and into the marketplace via the licensing of a patent to industry. Thus, Congress, led by Senator's Dole and Bayh, came to believe that changing the incentive system for academic R&D could lead to substantial increases in patenting and by extension, the licensing of those technologies to industry for exploitation.

As a result of this singular act and a series of subsequent ones, patenting of technologies in higher education almost immediately accelerated and continues to do so today (see Figure 1). For the first time, a process was established by which a university could much more easily obtain the rights to a university developed technology funded from federal dollars. Coupled with the high profile desire of the federal government and subsequently by states to use higher education as a prime driver of economic advancement, the financial gains envisioned through patenting, combined with the legitimacy now afforded to those who pursued them, had the desired effect – a shift toward commercial endeavors or what Slaughter and Leslie (1997) call academic capitalism.

Figure 1. Patenting Activity: 1974-1998.




While the Bayh-Dole Act served as the catalyst to the growing entrepreneurial phenomenon, another important force was at work. By the mid-1980s and early 1990s, it became increasingly clear that higher education was becoming a mature industry (Levine, 1997). Higher education was no longer enjoying the rapid growth experienced since the post-World War II years and instead had entered a new phase characterized by resource contraction and increased competition among institutions. No longer were colleges and universities more or less enjoying universal increases in student enrollments and comfortable resource flows. Instead, institutions were finding themselves in a competitive environment for students, facing reductions and/or increasing competition for state and federal support, and confronting a public with growing skepticism about higher education's contribution to the needs of society. Hence, colleges and universities were now also faced with the need for retrenchment as a cost reduction strategy while at the same time seeking to exploit new sources of revenue. As it regarded the latter, a typical reaction was to raise tuition (Institute for Higher Education Policy, 1999), at times into the double digits annually, but also to advance the commercialization agenda (Slaughter & Leslie, 1997). Thus, aggressively seeking to license patented technologies to business and industry was viewed as a potentially lucrative way of supporting the academic enterprise.

Figures Two and Three trace the growth in academic commercialization activity since 1991 via two common measures of performance with commercial activity, the number of licenses executed and the amount of licensing income received from licenses in a given year, the latter being a rough proxy for the success of a product in the market based on sales[1].

[1] University licensing income is derived in large part on royalties on product sales, typically in the 3-5% of sales range.

Figure 2. Licenses Executed: 1991-1999[2].

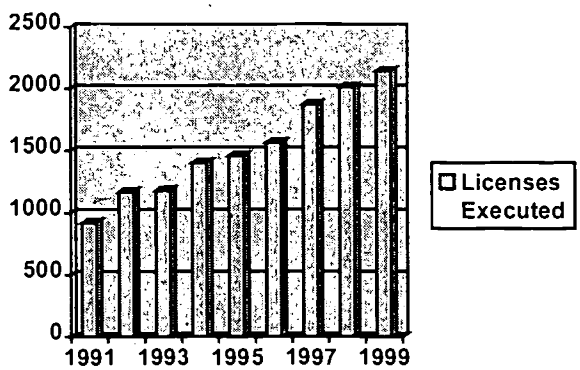
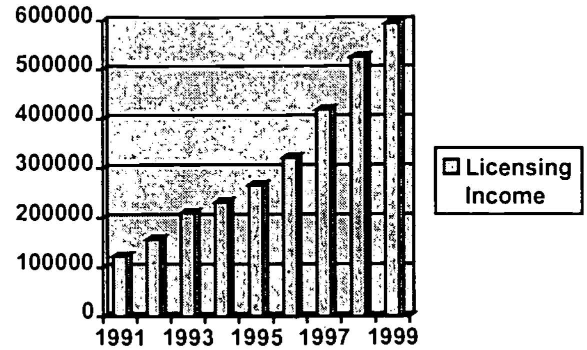



Figure 3. Licensing Income: 1991-1999.




As can be seen in the above graphs, the two measures of technology transfer, the process by which university research is commercialized into a marketable process or product, rose over the past decade. For licenses executed, this represents a 133% increase over the eight year period while for licensing income, a whopping 383% increase. Of particular note, however, is that as a source of institutional income, the growth in licensing revenues has far outpaced the increase in any source of academic R&D. For example, federal R&D over the same period increased 51% for the institutions reflected in the above graphs and industry R&D 75%. Although smaller in aggregate terms, since 1991, the above institutions saw their licensing income rise from 2 – 6% of federal R&D dollars and from 18-50% of industry R&D dollars. Given this reality, it is clear that research universities see where their most lucrative revenue enhancement opportunities lie and hence have responded aggressively into commercial activity, despite the considerable risks associated with its practice.

## *Purpose of Study*

Given this context, the purpose of this study was to investigate the effects of critical resource flows on technology transfer activity. Specifically, I investigate the impact of four particular sources of R&D revenues - federal, state, industry, and institutional - on a university's licensing orientation. By orientation I mean how heavily it is involved in licensing to smaller companies and start-ups, a more risky approach to technology transfer via the potential of firm failure and time to profitability (Brett, Gibson, & Smilor, 1991) or the more conservative route of licensing to large, established companies with the potential for consistent revenue streams but less opportunity for a blockbuster license (Gregory & Sheahen, 1991)[3]. Thus, after controlling for factors shown to be important in previous research on technology transfer performance, my research question is what impact, if any, do particular R&D revenue flows have on small or large company licensing? Utilizing national data from the Association of University Technology Managers, the National Science Foundation, and a variety of other sources, this study advances

[2] AUTM Licensing Survey: FY 1999; 9-year recurrent respondents; n=62. Note: For licensing income, dollars are in millions.
[3] Start-ups/small companies are defined as firms with 500 or fewer employees while large companies are defined as those with 500 or more employees. These are the definitions used in the annual licensing surveys of the Association of University Technology Managers.

our understanding of the role that critical R&D resource flows play in driving technology transfer activity.

## Theoretical Framework

The resource-based view of the firm (Barney, 1991; Penrose, 1959) offers a useful lens for understanding the impact that critical resource flows to a university can have on its technology transfer performance. The resource-based view posits that an organization's unique assets and capabilities, those that are difficult for others to imitate or copy, can help position an organization to outperform its competition in the marketplace. Researchers have noted the importance of a variety of financial, physical, human capital, and organization resources that are often sources of competitive advantage for an organization (Daft, 1999). Although the resource-based view was developed to explain for-profit firm performance, its application to higher education is reasonable given the increasingly competitive environment in which colleges and universities are currently situated.

Of particular relevance to this study are the important financial resources that are critical to supporting the R&D efforts of a research university. Specifically, the R&D revenues obtained from federal, industry, state, and institutional sources. Previous research on university technology transfer has demonstrated the importance of R&D resources and activity for economic development (Mansfield & Lee, 1996), the birth of new organizations (Flynn, 1993), and the robustness of academic partnerships with industry (Bowie, 1994). Hence, the resource based view of the firm would predict a positive relationship between levels of R&D funding and licensing activity. Those institutions enjoying greater R&D support would be expected to engage in higher levels of licensing to both small and large companies.

## Methodology

The sample in this study consisted of 104 doctoral extensive and intensive institutions in this country for which relevant data was available on each of the variables of interest. Geographically spread across the mainland United States and Hawaii, these institutions are engaged in the vast majority of university technology transfer activity. The 104 institutions were drawn from reported data for multi-year respondents in the annual licensing surveys of the Association of University Technology Managers (AUTM) for the period 1991 to 1998. The AUTM data is the only comprehensive source of information on the technology transfer activity of research universities in this country.

## Variable Measures

In addition to the data collected from the AUTM surveys, data on R&D funding was obtained from the National Science Foundation's annual reports on academic R&D. Additional data points were drawn from the National Academy of Sciences, the *Venture Capital Yearbook*, and *Peterson's Guide to Colleges and Universities*.

### *Dependent Variables*

Two dependent variables were included in this study and obtained from the 1996-98 AUTM licensing surveys. These outcome variables include the number of start-up/small company license issues and the number of large company licenses. As mentioned earlier, these are two primary manifestations of academic commercialization activity. In the case of start-up/small company licensing, universities that are heavily engaged in this type of licensing do so at greater risk of failure given that smaller companies are less resource rich and more often than not, lacking in adequate capitalization and human capital know-how (Gregory & Sheahen, 1991). Because small companies are often struggling financially, universities interested in licensing a technology to a small firm may have to rely on different financial structures, usually involving the substitution of equity for upfront licensing fees, potentially leaving a university with only worthless paper if the company fails or even languishes. Yet, even though many start-ups and small companies go bankrupt or under-perform for long periods of time, the occasional success story (e.g., a company that makes a high profile public offering of stock or is acquired by a larger firm) can mean substantial returns to the university (Bray & Lee, 2000), a craved for outcome by many universities engaged in technology transfer. Furthermore, the majority of licenses are with smaller companies, generally due to their regional proximity (United States General Accounting Office, 1998).

Licensing to large companies, on the other hand, is a more conservative approach to technology transfer but one more likely to result in speedier and more consistent returns via upfront fees and regular royalty payments (Gregory & Sheahen, 1991). Considering the fact that large public companies are generally much more financially sound than small companies and endowed with strong product development and marketing capabilities, licensing to large firms has obvious benefits to a university desiring to see a technology commercialized. Yet, doing so often requires a university to have national reach since large companies in relevant industries may not be based in an institution's state or region. In this sense, then, it can be harder to find a large company interested in licensing a technology than a small, unproven firm.

Given these key distinctions between start-up/small company and large firm licensing, then, investigating whether or not particular resource levels predict performance in these two regards is important. For this study, both dependent variables are continuous and operationalized as the average annual number of start-up/small companies or large firms to whom a university had licensed a technology between 1996-98.

### *Independent Variables*

#### *Federal R&D*

As mentioned earlier, the independent variables of interest in this study are four sources of R&D support in higher education, federal, industrial, state, and institutional. The first of these, federal R&D, represents the largest single source of support for university-based research for U.S. universities. In fiscal year 2000, it made up just over 50% of the R&D support mix for public universities but almost 75% of the mix for private universities[4]. These amounts, while they have increased 47% and 43% respectively since 1993, were one of the slowest growing sources of R&D and showed the largest decline in relative terms for both publics and privates as it regards its importance to the enterprise over the 1993-2000 period.

[4] Figures for these and subsequent sources of R&D are for the top 150 public and top 100 private institutions in this country as reported in the National Science Foundation's annual surveys of academic R&D expenditure.

Although federal R&D support has declined in relative importance, it still by far outpaces all other areas. Furthermore, given the federal government's interest in advancing the economic development interests of the country, it is increasingly common that granting agency terms involve the expectation of partnering with industry to facilitate the move of basic or applied research into the marketplace where it might best be developed into a commercializable technology for consumer purchase or use (Feller, 2000). Additionally, previous research has shown that federal R&D has led to important industrial innovations (Mansfield, 1995), even with basic research (Faulkner & Senker, 1994). Hence, in this study, I would expect that federal R&D would be positively predictive of both small and large company licensing. For this study, federal R&D is operationalized as the average annual federal R&D revenues for the period 1993-95.

*Industry R&D*

Although one of the smallest R&D sources in absolute terms (7% and 8% respectively in 2000), industry R&D was one of the faster growing areas of the university R&D budget, increasing 62% for publics and 53% for privates over the eight year period 1993-2000. Additionally, over this time range, its share of the R&D mix has remained fairly stable. Of greatest relevance to this study, however, is the fact that industry supported R&D is clearly oriented toward marketplace opportunities. Business and industry generally sponsors university-based research, even of the basic kind, with the belief that it will have practical applications, and generally with a shorter time frame expectation (Rosenberg & Nelson, 1993). Previous research on industry funded R&D has also shown that institutions with closer ties to industry are more likely to be involved in entrepreneurial activities such as forming spin-off companies, have faculty involved in for-profit venturing, and institutional equity participation in licensee firms (Cohen, et al., 1998; Roberts & Malone, 1996). As such, industry R&D would be expected to be positively predictive of at least small company licensing. Industry R&D is operationalized in this study as the average annual industry R&D revenues for the period 1993-95.

*State/Local R&D*

In 2000, state and local sources of R&D for research universities represented approximately 10% of total R&D support for public universities and a very small .02% for private institutions, figures that have remained roughly constant since 1993 despite 42% and 37% respectively. This source of funding represents state dollars directly targeted toward academic R&D activities by state and local governments separate from general appropriations made to public institutions. Although in aggregate terms this source of funding is very small for private universities, it is larger for public universities than industry sources and increasingly tied to specific economic goals of a state. Furthermore, recent research has shown that it has been particularly useful for leveraging other funds and fostering university-industry partnerships (State Science & Technology Institute, 1997) with its most common target being support of the biological and medical sciences (Battelle Memorial Institute and State Science & Technology Institute, 1998). Some examples of these initiatives include the establishment of science and technology offices in almost every state to stimulate new economy firm growth, often with active university involvement, specific technology infrastructure activities such as the Ben Franklin Initiative in Pennsylvania, and a variety of other workforce development programs designed to better support "home grown" entrepreneurial activity and bolster the supply of high technology employees (Battelle Memorial Institute and State Science & Technology Institute, 1998). Hence, even though these resources are not large in aggregate terms, the increasing emphasis on economic development outcomes from the research support would suggest a positive relationship between this source of R&D and licensing to small and large companies. State/Local R&D is operationalized in this study as the average annual state/local R&D revenues for the period 1993-95.

### *Institutional R&D*

The fastest growing source of R&D, particularly for public universities, is from institutional funds. This source of funding is derived through a portion of direct state and local government appropriations, tuition and fee revenues, and endowment income. It can also come through general purpose grants from outside sources and donor gifts targeted for research. Between 1993 and 2000, this R&D resource increased 68% for public institutions and 62% for private universities, the largest aggregate increase for any R&D source. Furthermore, it increased from 22% to 25% of the total R&D mix for publics, the largest percentage jump for any category as a share of the R&D mix.

Considering this data, it is clear that institutional resources are becoming an increasingly important contributor to R&D activity. Furthermore, since these are internal funds, the institution has much more control over their allocation, and thus, can potentially reduce dependence on the other outside sources of funding. Previous research has shown that organizations do seek to reduce their dependence on resource flows for which they have little control by bolstering internal sources of support – thereby better ensuring its long term survival (Pheffer & Salancik, 1978). Because of the increased legitimacy of economic development as a stated institutional aim (Slaughter & Leslie, 1997), then, it seems reasonable to assume that universities would also look to leverage institutional R&D resources toward those ends. Hence, institutional R&D should be positively predictive of both small and large company licensing. Institutional R&D is operationalized in this study as the average annual institutional R&D revenues for the period 1993-95.

## *Control Variables*

### *Venture Capital Munificence*

Previous research has shown that some other resource factors are important for explaining university technology transfer performance and hence are included in this study as controls. First, all is not equal in terms of a university's location. Institution's located in known entrepreneurial regions (e.g., Boston and Silicon Valley) would be presumed to have advantages over schools in less high growth areas. Previous research has demonstrated the importance of location for firm entrepreneurial activity (Pouder & St. John, 1996; Roberts, 1991) as well as university licensing and licensing income generation (Powers, in press). Thus, a continuous measure of environmental munificence, in this case venture capital availability, is included in the study based on the fact that the kinds of firms with whom universities license technologies often have a high need for venture capitalization (Roberts & Malone, 1996). This variable represents the average annual venture capital disbursement in a given state for the period 1993-95, data drawn from the *Venture Capital Yearbook*.

*Faculty Quality*

The quality of an institution's faculty has also been shown to be important for the development of high technology firms (Deeds, Decarolis, and Coombs, 1997; Finkle, 1998) as well as for the generation of higher levels of licensing income (Powers, 2000). As such, a faculty quality measure was included, generated from 1995 National Research Council data on the quality of university research faculty in the biological sciences, physical sciences, and engineering fields, the ones most likely to be involved in technology transfer.

*Technology Transfer Office Size*

A third control variable was included in the study that reflects the size of the technology transfer office, the entity responsible for executing licensing deals. Previous research on firm performance has generally shown that size of the company measured in number of staff can be an important predictor of various measures of performance (Deeds, Decarolis, and Coombs, 1997). Earlier research on university technology transfer performance also found a positive linkage between the number of technology transfer professional staff and licensing activity (Hauksson, 1998; Powers, 2000). Hence, a continuous measure operationalized as the number of years that the office has had at least .5 FTEs devoted to technology transfer was included in the study.

*Private/Public Status*

A final control variable included in the study is private/public status of a university. As mentioned earlier, given the differences in the amounts and makeup of particular sources of R&D funding for private versus public universities, it may be that there are differential effects for each type. Hence, a dummy variable that controls for private or public status is included in the study.

## Results

The data were analyzed using both univariate and multivariate statistical techniques. First, means and standard deviations were calculated followed by a correlation matrix. Results are shown in Table One.

Table 1.
Means, Standard Deviations, and Correlations

| Variable | Mean | s.d. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Small Companies | 12.52 | 18.82 | 1.0 | | | | | | | | | |
| 2. Large Companies | 7.78 | 10.82 | .54** | 1.0 | | | | | | | | |
| 3. Venture Capital | 262.10 | 552.75 | .35** | .18* | 1.0 | | | | | | | |
| 4. Faculty Quality | 2.87 | .78 | .50** | .58** | .34** | 1.0 | | | | | | |
| 5. TTO Size | 4.58 | 9.23 | .70** | .65** | .28* | .52** | 1.0 | | | | | |
| 6. Priv/Pub | .29 | .47 | .07 | .28* | .33** | .39** | .24* | 1.0 | | | | |
| 7. Federal R&D | 79,967 | 68,847 | .58** | .72** | .32** | .76** | .69** | .32** | 1.0 | | | |
| 8. Industry R&D | 8,945 | 8,761 | .41** | .43** | .10 | .45** | .48** | .08 | .63** | 1.0 | | |
| 9. State R&D | 10,787 | 14,981 | .31** | .19* | -.11 | .06 | .16 | -.36* | .11 | .26* | 1.0 | |
| 10. Institutional R&D | 24,501 | 22,084 | .36** | .17* | -.05 | .26* | .19* | -.34* | .34** | .43** | .46** | 1.0 |

Note: Correlations above |.31| are significant at p<.01; those above |.17| are significant at p<.05. N's vary from 101 to 104 because of missing data.

As can be seen in the above table, the average annual number of licenses that a university had with start-ups and small companies for the period 1996-98 was 12.52. The sample universities also had on average 7.78 licenses with large companies. The average university had \$79.97 million in federal R&D revenues, \$8.95 million in industry sponsored research, \$10.79 million in state R&D revenues and \$24.5 million in institutional R&D dollars. Furthermore, the average level of venture capital disbursement in a state was \$262 million while the sample had a mean faculty quality rating of 2.87 (on a 1-5 scale) and 4.58 FTE of staff devoted to technology transfer. Lastly, 32 of the schools were private and 70 were public.

The correlation matrix suggested a need for more intensive collinearity diagnostics given that some of the independent variable correlations were moderately high, although all below the .8 rule of thumb (Lewis-Beck, 1980). Variance inflation factors (VIFs) and tolerances were computed for each variable. Only two of the VIFs were in the moderate range, 5.5 for federal R&D and 3.5 for TTO size respectively, with the rest being under two, all well below the concern level of 10 that previous researchers consider the threshold for collinearity problems (Von Eye & Schuster, 1998). As it regards tolerances, the rule of thumb is that those below .1 are suggestive of collinearity (Norusis, 1998). With the exception of federal R&D (.182) and TTO size (.284) all were at least .5 or higher, again indicative of model acceptability. As a final test, however, regression model pairs were run with and without the federal R&D and TTO size variables respectively to see if it substantively changed the results. No differences were found, indicative of the absence of collinearity.

Lastly, additional tests of the data for regression violations were investigated. Histograms and normal probability plots were explored with the result indicating the need to log transform the two dependent variables and the venture capital munificence variable to adjust for skewness in the data.

Given the appropriateness of the data for regression analyses, a hierarchical regression procedure was employed such that the control variables were entered in the first step (the partial model) and the independent variables in step two (the full model). The results of this analysis with standardized Beta weights and levels of significance at the .1, .05, .01, and .001 levels are shown in Table 3 below.

Table 3
Regression Results of All Models

| Variables | Model 1: LNSMCOMP N=104 | | Model 2: LNLGCOMP N=101 | |
|---|---|---|---|---|
| | Partial Model | Full Model | Partial Model | Full Model |
| LNVENMUN | .13+ | .12+ | -.05 | -.05 |
| FQUAL | .52*** | .30*** | .55*** | .29** |
| TTOSIZE | .40*** | .28*** | .37*** | .16+ |
| PRIVPUB | -.22*** | -.07 | -.05 | .05 |
| FEDR&D | | .24* | | .38** |
| INDR&D | | -.04 | | .06 |
| STATER&D | | .07 | | .16* |
| INSTR&D | | .23** | | .04 |
| F-Value | 46.62*** | 31.24*** | 35.27*** | 24.85*** |
| Adjusted $R^2$ | .64 | .70 | .58 | .66 |

*p<.05; **p<.01; ***p<.001; +p<.1

The regression results indicated that the two models explained a significant amount of the variation in each of the dependent variables and that including the R&D variable set significantly improved the model fit in each case (p=.001). The full models explained between .66 and .7 percent of the variance in the respective analyses and the F-statistic was highly significant in both cases, findings indicative of good model fits and the value-added offered by using the full models for drawing inferential conclusions.

In Model One predicting start-up/small company licensing, faculty quality and TTO size were positively significant (p<.001) in the partial model with venture capital munificence also approaching significance in the positive direction. Private/public status was negatively significant in the partial model. All of these variables maintained these levels and direction of significance in the full model except for private/public status which was no longer significant. Federal and institutional R&D resources were also positively significant in the full model. These results provide confirmatory evidence that as a resource for competitive advantage, the quality of the faculty, size of the technology transfer office, and funding from federal and institutional sources appear to be associated with stronger licensing performance with start-ups and/or small firms. Additionally, private institutions do not enjoy advantages in this regard over public schools.

In Model Two involving licensing to large companies, faculty quality and TTO size was positively significant in the partial model (p<.001), but only faculty quality remained significant in the full model (TTO size only approached significance). Federal R&D support was again a significant predictor of the outcome variable. State R&D support was also positively predictive of large company licensing. These results again suggest the importance of federal R&D funding for licensing performance but also the value of state R&D dollars. Once again, there appears to be no performance differences in large company licensing between private and public research universities.

Discussion

In this study, I investigated the affects of a set of critical resources on two important outcomes of technology transfer, the number of licenses with start-ups/small firms and licenses with large firms. Four sources of R&D support for universities were explored, federal R&D, industry R&D, state R&D, and R&D dollars from internal institution sources. Furthermore, I included three control variables, venture capital munificence, the quality of science and engineering faculty, and the size of the technology transfer office, that have been shown to be important with other forms of technology transfer performance. Lastly, I included the status of a university as private or public to control for possible performance differences in this regard.

A first notable result was that federal R&D was a significant positive predictor of performance in both models. In other words, institutions with larger amounts of federal R&D support outperformed institutions less well endowed with resources of this type. This result is consistent with previous research on university technology transfer. DiGregorio & Shane (2001) and Powers (2001) both found federal R&D was positively predictive of university start-up company formation, the situation when a university itself decides to form a new company around a university developed technology rather than license it to a non-affiliated outside firm. Powers (In Press) also found federal R&D to be positively predictive of the level of university patenting activity.

This result suggests that federal interest in economic development as manifested through policy structures and incentives for commercialization appears to be having the desired effect. Universities are using this most important source of R&D financing to advance a commercialization agenda with firms of all sizes. Upon close examination of federal funding expectations and processes, two explanations for this finding seem reasonable. First, the social contract between the federal government and the nation's research universities has evolved to one that could be characterized as a triple-helix (Etzkowitz & Leydesdorff, 1999) whereby universities are considered equal partners with government and industry for the conduct of R&D and ultimately industrial innovation. As such, it has become legitimate and increasingly expected that university recipients of federal grants and contracts consider the ultimate utility of funded research rather than pursuing it for its own sake. Given the importance of legitimacy to organizational success within an institutionalized industry like higher education (Scott, 1995), universities have come to see the political payoffs of adopting the more entrepreneurial orientation of the new social contract (Bozeman, 2000). Thus, universities are touting their economic development contributions like never before.

Second, although as a share of the R&D funding mix federal dollars have declined, federal support for the life sciences has grown precipitously while other areas have increased only slightly (National Science Foundation, 2001), a trend that has been underway for decades[5]. Funding of non-life sciences fields has been under $2 billion while in 2001, federal funding for the life sciences reached almost $10 billion, much of this support coming from the National Institutes for Health. What is most relevant about this trend for this study, however, is that agencies such as NIH are less likely to impose cost sharing requirements on grantees (i.e., the expectation of matching institutional or industry funds in order to get the grant), a phenomenon

[5] Measured in constant 2001 dollars.

that is becoming increasingly burdensome for institutions (Feller, 2000). Thus, when the federal government is less intrusive in granting requirements, it may be more effective in actually achieving the end goal of stimulating a practical science (Tornatzky, 2000) as manifested by the positive relationship between federal R&D (made up in large part by life sciences funding) and both measures of technology transfer performance.

Although federal R&D was the only significant independent variable in both models, the significant finding for institutional R&D with start-up/small company licensing was also of noteworthy importance. As described earlier, institutional funds are resources that the institution chooses to allocate itself to R&D activities. One explanation for the finding in this study is that universities are perhaps even greater risk takers than previously thought. Specifically, they are inclined to devote institutional resources toward potential high-risk but high-return activities as opposed to going the large company route. Considering that institutional R&D is the fastest growing source of academic R&D and the one for which the institution can exercise the most control, it is arguably the best barometer of entrepreneurial orientation of any of the R&D funding areas. It seems, then, that universities may be seeking to actively position themselves as prime drivers of state and regional economic development, the kind of outcome more likely occur through start-up/small company licensing than via the large company route (Tornatzky, 2000). Considering that federal granting agencies increasingly require institutional matching funds, it may also be that institutional resources devoted to academic R&D are having the greatest practical impact at the state or regional level.

An alternative or parallel explanation may be that many universities, particularly those new to the technology transfer enterprise, do not have the national reach necessary to do well with large company licensing and hence are de-facto forced into a predominately start-up/small company licensing strategy. Thus, any licensing that occurs as a result of institutional R&D activity by default is directed toward the more risky form of licensing. Hence, even if a university wanted to pursue more large firm licensing deals, their opportunities for doing so may be limited, especially when they are in fairly isolated areas of the country away from major metropolitan centers. As a result, the strong isomorphic tendencies of universities to "follow the pack" down the path of greater commercial involvement, may not be serving all institutions well or at least may represent a sub-optimum investment of limited resources. This reality is of particular concern given the fact that relatively few institutions are substantially benefiting financially from their licensing activities and those that do, tend to do so as a result of a few blockbuster licenses (United States General Accounting Office, 1998). While the negative repercussions of this start-up/small company strategy was mitigated somewhat by the economic boom period of the time frame studied in this research, it becomes especially problematic during economic downturns as has been characteristic of the last two years where we have seen a rise in small company failures and reductions in capital availability, the lifeblood of young companies heavily engaged in product development. Thus, institutions today that may have been betting on big returns on stock equity are more likely to be left with worthless or near worthless paper.

A third noteworthy finding involves the state R&D variable as a significant predictor of large company licensing. In recent years, legislators and their agents have been eager to enhance the economic vitality of their states. Rare is the occasion when a governor in a state of the state address or a legislator in a debate on the state house floor does not invoke the desire to advance a new knowledge based economy agenda with the hoped for goal being the establishment of their own version of Silicon Valley or the Route 128 high technology corridor. Believing that their institutions of higher education can play an important role in helping achieve these noble ends, state leaders have pressed universities hard to reorient themselves to a state level economic development agenda through both carrot and stick means. Whether through performance based funding mechanisms, the creation of special RFP opportunities, or through incentive programs for higher education and business partnering (National Science Foundation, 1999; State Science & Technology Institute, 1997), states have actively sought to leverage higher education for economic development purposes.

Given the results in this study, however, it appears that they are achieving this with large company licensing, but not the smaller firms that are more likely to be "home grown" and the core drivers of state based economic development (Tornatzky, 2000). In other words, state R&D funds appears to be stimulating large company licensing, the ones more likely to be located out of state. While this finding in not necessarily bad (i.e., it better ensures a steady income flow to a university and some of these large companies may be in state), it does suggest that the hoped for outcome of stimulated in-state small company development is not occurring simply as a function of state academic R&D funding programs. Considering that over 75% of university based start-ups are established near to the parent university (AUTM, 1996), the finding of non-significance in this study is an important one for states considering the impact of their economic development policies.

While the above independent variables were significant in one or more of the models, industry R&D support was not significant in either model. This was a somewhat surprising result, especially for start-up/small company licensing, since in previous research aggregate industry R&D was positively predictive of university start-up formation alone (Powers, 2000; DiGregorio & Shane, 2000). Yet, the sample in this research included institutions in the new two top tiers of the Carnegie Classification, a broader group that included more institutions less well endowed in terms of R&D revenues received. Hence, it may be that industry R&D is predictive of start-up/small company licensing only beyond a certain level of industry R&D.

The non-significant finding may also be a function of the fact that licensing opportunities are often not the primary reason for industry to fund academic R&D. In two recent studies of industry professionals inquiring about their reasons for partnering with universities, they cited faculty consulting as the most important reason followed by professional education, recruiting, joint R&D, and then technology licensing (BankBoston, 1997; Blumenthal, Causino, Campbell, & Louis, 1996). Furthermore, even though industry sponsors of academic R&D often include contractual clauses giving them the right of first refusal on licensing opportunities stemming from the research, it does not necessarily mean they will desire to license the developed technology or be opposed to a non-exclusive license (Tornatzky, 2000).

As it regards the control variables, the quality of the science and engineering faculty was significant in both models while the size in professional staff of the technology transfer office was significant in the start-up/small company licensing model but only approached significance in the large company licensing model. Venture capital munificence approached significance in the start-up/small company model but was not significant in the large company model. Taking the faculty quality result first, this finding was consistent with those found in previous research on university start-up company formation (DiGregorio & Shane, 2000) and patenting, general licensing, and licensing income (Powers, in press). Clearly, the quality of one's faculty is an important source of competitive advantage as would be predicted by the resource based view of the firm. Universities with stronger faculty reputations appear to enjoy performance advantages over universities with less reputable faculties in regards to a number of important technology transfer outcomes. For the finding involving the size of the technology transfer office variable, it too aligns with previous research (Hauksson, 1998; Powers, in press) suggesting performance advantages for universities with larger licensing staffs. In terms of the venture capital finding of near significance in the start-up/small company model, it too was a result in alignment with previous research on start-ups (Powers, 2000), albeit weaker in strength. The finding of non-significance for large company licensing is not necessarily surprising considering that large companies are not generally dependent on venture capital. Additionally, universities located in venture capital poor states are probably forced to seek out of state licenses (i.e., the in-state small business climate is poor), and likely with larger companies. Lastly, there were no private-public differences found in the full models, suggesting no performance differences by institutional type.

## Policy and Practice Implications

The results of this study suggest some important policy and practice implications for federal and state policy agents as well as institutions seeking to advance their technology transfer programs. First, for federal policy makers, this study suggests that initiatives such as the Bayh-Dole Act and subsequent legislative actions to stimulate heightened university interest in practical applications for R&D has had the desired effect. Furthermore, staying the course of funding primarily basic research in higher education has not appeared to be a stumbling block to commercialization, with some evidence that basic research may even have a greater likelihood for commercialization than applied R&D (Rogers & Bozeman, 1997). However, federal policy makers would be wise to use caution in enacting steps that appear to be micro-management of the academic R&D enterprise since some evidence exists that these can be onerous and potential disincentives for institutions (Feller, 2000). The increased competition for federal R&D dollars combined with the increasingly common requirements for institutional matching funds is also a source in itself of escalating costs in higher education since universities are having to reallocate their own internal R&D resources to remain competitive in the federal R&D game (Florida, 1999). Finally, so long as federal policy makers recognize that federal R&D may be more effective at stimulating start-up/small company licensing than large company licensing, this suggests no need to reorient granting agencies to encourage more large company support.

The findings of this study also have implications for state policy makers. First, state/local R&D investment appears to be having an affect on large company licensing, but not start-ups or small companies generally assumed to be important sources of innovation and state level economic development. Thus, state officials would be wise to review their current practices and the degree to which they can enhance the incentives for licensing to start-ups and small companies within a state. In states where there is a healthy environment for small companies to thrive, state agencies might simply offer granting opportunities to in-state institutions that are specifically tied to regional economic development needs and the licensing of technologies to in-state firms. Furthermore, establishing prizes for faculty who have been especially successful in commercializing a technology in-state or offering matching funds to leverage federal R&D dollars are examples of other ideas that could be of benefit.

For states where the climate for entrepreneurial firms is less robust, states would be wise to emphasize a combination of small business enhancement programs as well as the above incentives to universities to develop partnerships with them. For example, they might consider R&D tax credits for small firms, foster the development of new venture funds, remove legal barriers to technology transfer that might exist such as restrictions on university or faculty equity participation, and in general, engage in other climate enhancement initiatives. A number of states are beginning to show success with these kinds of efforts at fostering in-state university-industry technology transfer and regional clusters of innovation (Porter, 2002; State Science & Technology Institute, 1997; Tornatzky, 2000).

For institutions, there are also some important implications. First, it is clear that enhancing the quality of one's faculty has a strong and positive affect on technology licensing. Florida (1999) argues that focusing on faculty talent enhancement can do more to strengthen the value of institutions as an economic development engine than perhaps any other single action. A core competence of a university its ability to produce knowledge and has history has shown, building a faculty that can do this will naturally lead to important break-through innovations. Yet, the recent expansion of the university mission to embrace a commercialization agenda has not been an easy marriage in higher education. Considerable and legitimate concerns exist as it regards potential conflicts of interest, commitment, and internal equity for those institutions engaged in academic entrepreneurship (Campbell & Slaughter, 1999). Yet, institutions that have enacted clear policies regarding such issues as secrecy in academic research, full disclosure of commercial involvement by faculty, and ethical misconduct can manage this unfamiliar territory without undermining the principles on which academic research has been built in this country.

Given reductions in state appropriations for higher education and the increased competition for federal R&D resources, it is perhaps not surprising that universities have engaged in a resource dependence reaction (Pfeffer & Salancik, 1978; Slaughter & Leslie, 1997) by increasing their own funds for R&D activity. Yet, I would caution universities that this can come at the expensive of other important functions of the institution including the quality of teaching and added pressure on tuition, issues of particular saliency to multiple external stakeholders. This reality, then, would suggest the need to make even more clear to outside observers the important contributions that higher education makes to the greater good of society and in ways that emphasize the tradeoffs that can occur. Hence, as it regards economic development, institutions could better explain what they provide as a source of skilled labor, job creation, and overall economic vitality as some institutions have done (NASULGC, 1997), but also craft what impact state and federal tuition, financial aid, and/or R&D policies can have on their ability to successfully meet their multiple mission obligations.

## Limitations and Opportunities for Future Research

While this study has much to offer, it is not without its design limitations suggestive of further research. First, as other researchers have pointed out, there is considerable utility in understanding the phenomenon at the institutional level in ways that an archival study cannot capture. For example, the culture of an institution is often cited in the literature as a prime reason for why some institutions are more successful than others with technology transfer or why some institutions may be more responsive to external factors driving their interest in pursuing a technology transfer agenda. As such, a survey or interviews of technology transfer professionals or faculty involved with commercial activities would be useful for better understanding the culture of entrepreneurship.

Second, the time frame in which I studied this phenomenon was one characterized as a strong economic expansion where entrepreneurial activity was highly in fashion (e.g., the dot-com boom). Although studying the topic over a consistent period of time (good or bad) is useful for explaining away economic climate changes, today's weaker economy may suggest a different environment for university entrepreneurial activity than the one I studied. Relatedly, the university technology transfer phenomenon is a rapidly evolving one as more and more institutions become involved in patenting and licensing, suggestive of a true time series analysis as a useful follow-up to this study.

Lastly, a number of my variables could have been operationalized as ratios and not aggregate figures, something that researchers in this topic area believe can be valuable for capturing relative differences among institutions (Tornatzky, 2000). Thus, follow-up study in which some of the independent variables are used to develop relative comparisons of performance or to develop key performance indices would be a useful extension of the research reported here.

## Conclusion

This research study sought to better understand the affect of critical resource flows on U.S. university technology transfer performance in two areas, start-up/small company licensing and large company licensing activity. Given the seemingly insatiable appetite for revenue stream enhancement within an environment where commercial activity has become increasingly legitimate, this study is useful for informing its responsible practice. Considering the fact that higher education appears to have moved solidly into a maturing industry era (Levine, 1997) in which they must be more entrepreneurial to remain competitive, this study offers policy makers as well as institutional leaders valuable insights on how the triple helix relationship (Etzkowitz & Leydesdorff, 2000) between government, universities, and industry can be enhanced.

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