The Halo Effect and Technology Licensing: The Influence of Institutional Prestige on the Licensing of University Inventions

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### Abstract

Sociologists and organizational theorists have long claimed that the processes of knowledge creation and distribution are fundamentally social. Following in this tradition, we explore the effect of institutional prestige on university technology licensing. Empirically, we examine the influence of university prestige on the annual rate of technology licensing by 102 universities from 1991 to 1998. We show that institutional prestige increases a university's licensing rate over and above the rate that is explained by the university's past licensing performance. Because licensing success positively impacts future invention production, we argue that institutional prestige leads to stratification in the creation and distribution of university-generated knowledge.

## Introduction

Sociologists and organizational theorists have long claimed that the processes of knowledge creation and distribution are fundamentally social. For example, Merton's (1968) seminal work on the Matthew effect demonstrated that, for the same quality of scientific research, more prestigious scientists receive more citations than less prestigious scientists. In this paper, we extend the concept of prestige to the domain of university technology licensing. We examine the proposition that universities' institutional prestige will influence their ability to license inventions.

Prior research on the licensing of university inventions does not pay much attention to questions of institutional prestige (Henderson et al, 1998; Rosenberg and Nelson, 1994; Mowery et al, 2001). Drawing primarily from an economic paradigm, this research has argued that a university's ability to license its inventions is influenced largely by the current and past invention quality. Past licensing performance enhances current licensing performance because past performance provides a signal of future invention quality to potential buyers (Allen, 1984). While providing useful insights into university technology licensing, this research stream fails to incorporate sociological findings that an institution's prestige is influenced by organizational traits other than past performance, and that general university prestige influences both the production (Allison and Long, 1990) and diffusion of academic knowledge (Crane, 1965; Merton, 1968). As a result, to date, no research investigates the effects of institutional prestige on the ability of a university to license its inventions.

Examining the influence of institutional prestige on university technology licensing is important for at least four reasons. First, from a theoretical perspective, disentangling the effects of prestige from past performance is important. Although sociologists and economists agree that a buyer's relative positive or negative perceptions of an organization influences exchange transactions (Podolny, 1993), they disagree about the origins of these perceptions. Economic research has assumed that these perceptions emerge directly from past performance and influence exchange transactions by providing signals of quality. In contrast, sociological research has argued that these perceptions are not only tied to an organization's past performance, but are also strongly associated with the organization's general prestige relative to peer institutions. Moreover, the sociological construct of prestige holds that external perceptions of an organization influence exchange transactions, not only by signaling the quality of an organization's goods, but also because positive external perceptions about the general organization influence external perceptions of its goods (Shenkar & Yuchtman-Yaar, 1997; Perrow, 1961). Therefore, understanding the roles that university prestige and past performance play in university licensing transactions will help increase our understanding of the relationship between an organization's general prestige, its past performance, and exchange transactions.

Second, there have been no attempts to empirically examine the influence of organizational prestige on exchange transactions using both a direct measure of prestige and a direct control for past performance. Much of the prior research has used indirect proxies of performance, such as past market presence (Podolny, 1993) and occurrence dependence (Podolny and Stuart, 1995). However, because past performance and prestige are positively correlated (Podolny, 1993), the use of indirect measures has limited the ability of researchers to claim that prestige effects are not solely due to the signaling effect of past performance or unobserved dimensions of organizational capability.

Moreover, two studies that do control for past performance through the use of direct measures (Benjamin and Podolny, 1999; and Stuart, 1998), suffer from imprecision in the measurement of prestige. Rather than measure prestige directly, these studies infer it from organizational affiliations, arguing that actors prefer to associate with other actors of the same status. Unfortunately, affiliation is an imprecise measure of status because social ties are determined by many factors other than the desire of high status entities to limit their interactions to other high status entities. In particular, affiliation depends heavily on geographic proximity, leading studies

that use affiliation as a proxy for status to incorrectly attribute the effects of geographically motivated affiliation to status.

Third, prior studies of prestige effects do not look at markets for knowledge, but instead look at hybrid inter-firm relationships or markets for physical goods. For example, Stuart (1998) examines the formation of hybrid inter-firm relationships (strategic alliances) in the semiconductor industry. While this article provides useful evidence of prestige effects, questions remain about the generalizability of its findings to the purchase and sale of knowledge assets through markets. Knowledge differs from physical goods (such as semiconductors) because it is indivisible, uncertain, and difficult to appropriate, making its purchase and sale quite different from the purchase and sale of physical goods (Arrow, 1962). Moreover, market-based transactions, such as licensing, differ from hybrid inter-firm relationships, such as strategic alliances, on a variety of dimensions that prestige could impact, including modes of communication, organizational commitment, organizational preferences, approach to conflict resolution, climate, and flexibility (Powell, 1990). If prestige is more important for facilitating market-based transactions than for inter-firm relationships and is more important for knowledge assets than for physical assets (Podolny, 1993), the licensing of knowledge may depend more on prestige more than other types of business activity. Consequently, empirical examination of the effects of prestige on markets for knowledge provides an important test of the scope of prestigebased arguments.

Fourth, the specific focus of our investigation on the effect of prestige on university technology licensing is important because university technology plays an important role in economic growth and technical advance in this country (Adams, 1990; Jaffe, 1989; Rosenberg and Nelson, 1994). U.S. universities generate thousands of patents each year, accounting for approximately 8 percent of the total patents issued. Moreover, the licensing of university-generated intellectual property accounted for \$40 billion of economic activity last year (AUTM,

1999). Therefore, explaining the effects of prestige on university technology licensing is important to understanding the knowledge economy.

Unfortunately, prior studies, even those that consider technology (e.g., Stuart, 1998; and Podolny and Stuart, 1995), do not explore the potential for prestige to create large inefficiencies in the university technology licensing market. Licensees of university technology may exhibit risk-averse behavior by preferring to transact with more prestigious universities. In addition, licensees may be drawn to more prestigious universities because the university's prestige will help them attract additional resources to commercialize technology. These behavioral patterns may create significant inefficiencies in markets for university technology, as more prestigious universities may license more technology than their past performance at technology licensing suggests that they should.

In this study, we examine the rate at which 102 universities license their inventions over the period 1991-1998. We find that institutional prestige influences the number of licenses that a university generates annually, even after controlling for the university's past licensing performance, its staffing policies, its magnitude of technology production, the density of high technology firms and other universities in its region, and its sources of research funds.

#### The Setting: University Technology Licensing

The specific setting we examine is the market for university technology. Many universities retain the rights to inventions developed by faculty, staff, and students that make material use of university resources in their development. As a result, those universities, not the inventors themselves, make decisions about the disposition of inventions made with university resources.

University policies often require faculty, staff, and students to file invention disclosures when they believe that they have invented new technologies. University personnel, located in offices of technology transfer, review these disclosures. Technology transfer office personnel determine whether the disclosures represent actual inventions because university personnel sometimes believe that they have invented new technology, when, in fact, they have not. In addition to determining whether a disclosure represents an invention, the technology licensing office personnel determine whether or not to patent the invention. Because of the legal monopoly that patents provide, they are the preferred mechanism for protecting universities' intellectual property. However, not all inventions can be patented. To be patented an invention must be novel, non-obvious to a person trained in the prior art, and valuable. Thus, only a portion of disclosures made by university inventors will result in new patents.

Many universities seek to earn financial returns from their inventions. Because universities are in the business of conducting research and educating students, they do not develop products and services directly from their inventions. Rather, they generally seek to license these inventions to private sector firms who use this technology to create new products and services in return for a fee.

To license their inventions, universities must market them; and technology-licensing personnel are in charge of this marketing effort. Along with the inventors, licensing officers identify and target those private sector entities most likely to be interested in the new technologies. The licensing officers write letters and make phone calls to those parties and invite them to examine the technology.

The licensing officers also manage the interaction with potential licensees. Licensing officers interact with individuals who come to the university in search of valuable technology, directing them to technologies that might be available for license, arranging for meetings with inventors, and coordinating visits to university labs. In addition, licensing officers help to arrange future research and development work on the technology through contract research at the university, or for external financing through contacts with venture capitalists and other financial institutions. Furthermore, when a potential licensee is interested in contracting for a technology, the licensing officer negotiate the terms of the contract.

University technology licensing contracts generally involve two components, an up-front cash payment and an ongoing royalty that is generally specified as a percentage of sales (Feldman

et al, 2002). Up-front fees generally range from \$10,000 to \$250,000 and ongoing royalties from between 2 percent and 15 percent of sales (Bray and Lee, 2000). Very often with small and startup firms, and increasingly with other firms as well, universities capitalize the up-front fees and take their payments in equity (Feldman et al, 2002).

The licensing of university-generated intellectual property is an important economic phenomenon. University patents account for over 8 percent of total patents in the United States (Henderson et al, 1998). Moreover, these institutions generated 12,324 new invention disclosures, 5,545 patent applications, and 3,900 new licensing agreements in 1998 (AUTM, 1999).

University technology licenses generate significant economic value. Roughly 8,308 of them yielded income in 1998, and 25 percent led to a product that had sales in the marketplace. As a result, U.S. and Canadian educational institutions received \$862 million in licensing income in 1998 (AUTM, 1999). Furthermore, the Association of University Technology Managers estimates that this licensing activity generated 270,000 jobs, \$5 billion in tax revenues, and \$40 billion in total economic activity.

## **Just Past Performance or Something More?**

According to both economic and sociological theory, external perceptions of an organization influence the likelihood that buyers will undertake exchange transactions with that organization. However, economic and sociological-based explanations for the mechanisms behind these influences differ substantially.

## Reputation for Past Performance

Economic theory argues that buyers form rational expectations of the quality of goods and services offered by sellers by observing the sellers' past products and actions, and that these reputations influence subsequent purchasing decisions (Wilson, 1985). Reputation for past performance serves as (an imperfect) substitute for direct knowledge that is particularly influential in situations where it is difficult to ascertain quality (Shenkar and Yuchtman-Yaar,

1997). Given uncertainty, buyers are more willing to transact with organizations that have better past performance because past performance signals future performance. Thus, in economic models of reputation, past performance, future expectations, and the likelihood of transactions, are tightly coupled (Weigelt and Camerer, 1988). In the context of university licensing, reputation arguments suggest that universities that have better past licensing performance should be more likely to license their current inventions than universities that have worse past licensing performance.

### Prestige

Sociological theories of prestige argue that buyers' decisions are more loosely linked to past performance than economic theory would suggest (Perrow, 1961). Sociological theories suggest that buyers are influenced by an organization's general prestige, that is, the relative esteem in which an organization is held in an "ordered total system of differentiated evaluation" (Parsons, 1951: 132). Prestige arguments claim that, while the organization's past performance influences external perceptions of the value of its current outputs, other organizational attributes (Perrow, 1961), such as organizational size, age, network position, (Young and Larson, 1965; Shrum and Wuthnow, 1988), members' social status (Minnis, 1953), structure, and the status of its exchange partners (Podolny, 1993) also influence these perceptions.

Organizational prestige influences exchange transactions by making a high prestige producer more likely than a low prestige producer to consummate a deal to sell a product or service of equal quality. Four mechanisms underlie this effect. First, buyers attribute their positive perceptions of a high prestige organization to its outputs, thereby increasing the outputs' perceived value through a "halo effect" (Crane, 1965; Perrow, 1961). For example, Perrow (1961) found that patients relied on general hospital characteristics *unrelated* to their medical needs (such as building design) and the general evaluation of "validating groups" to decide whether or not to seek particular health services at the hospital in question. Second, prestige increases an organization's visibility, thereby enhancing the likelihood that potential buyers will know about an organization's outputs (Lewin, 1935; Granovetter, 1985). Context influences what information people pay attention to, and the meanings they ascribe to information (Asch, 1940). Thus, products from more prestigious organizations receive greater visibility than products from less prestigious organizations (Crane, 1965; Merton, 1968). For example, Merton (1968) found that a scientist's prestige influenced the amount of credit he or she received for a scientific paper because articles of equal academic importance written by less prestigious authors are less likely to be read than articles by more prestigious authors.

Third, prestige increases the credibility of an organization's claims about quality. People often consider information from prestigious sources to be more valuable than information from less prestigious sources (Hovland et al, 1953). For example, if researchers at MIT and a small university in the Midwest both develop the same invention, past research suggests that MIT's claims about the commercialization-potential of the technology would be viewed as more credible than similar claims by the small Midwestern university.

Fourth, buyers prefer to transact with more prestigious organizations because interaction with higher status others increases their own prestige (Tallman and Shenkar, 1996). This creates a dynamic in which "more customers simply flow to the producer without the producer actively seeking them out" (Podolny, 1993: 838). In the context of our study, this means that buyers prefer to search for inventions at, and transact with, more prestigious universities.

In summary, sociologists argue that institutional prestige increases the likelihood of exchange transactions through four mechanisms that operate over and above the effect of past performance: the halo effect, increased visibility, increased credibility, and buyer preferences to transact with more prestigious others. These mechanisms lead us to the following hypothesis, which we test empirically: *A university's prestige will increase its rate of licensing over and above the rate expected from its past licensing performance*.

### Methodology

### Sample

We explore the licensing rate of university-assigned inventions from 102 U.S. universities from 1992-1998 as a function of university attributes measured from 1991-1997. Because we examine whether institutional prestige influences the rate of technology licensing from universities, we first identify the population of institutions that are at risk of licensing technology. To be at risk of licensing technology, a university must have faculty, staff and/or students who invent licensable intellectual property. Because social science and humanities research does not result in licensable inventions, being at risk of licensing effectively requires departments in engineering or science. Thus, most liberal arts colleges are not at risk of licensing and lie outside the population we examine.

Moreover, universities can only be at risk of licensing technology if the institution asserts a property right over technology produced by its faculty, students, and staff. Some institutions do not assert these rights, leaving them to the inventors themselves. Although people at institutions that do not assert property rights can license technology, their institutions cannot. In these cases, examining the effect of the university on the licensing process is not meaningful; therefore, these institutions lie outside of the population we examine.

One good sampling frame for the population of institutions that assert property rights over technologies that their faculty, staff, and students invent is the population of universities with technology transfer offices. Technology transfer offices are units of university administration whose mission is to manage the university's intellectual property. Because these units track intellectual property that is created through the use of university resources and manage the licensing process, it is extremely rare for institutions whose faculty, staff or students produce technological inventions and which assert property rights over them, not to have these offices.

The membership of the Association of University Technology Managers (AUTM) thus represents the population of institutions at risk of licensing their inventions. We believe that the AUTM sample accurately represents the population of university technology licensing offices because we were unable to identify any universities that have technology licensing offices but are not members of AUTM. Our initial sample includes all of the members of AUTM.

AUTM annually surveys universities to obtain information about their intellectual property activity. AUTM collects data on licensing, technology office staff, funding, and invention disclosures, among other variables. Because AUTM has only collected licensing activity data since 1991, we examine panel data on licensing activity for the 102 universities for which licensing data exists for at least two years during this period.

In our analysis, we define a university as a system that operates under a single set of intellectual property rules. When university systems have disparate campuses governed by the same policies or procedures, we aggregated data from the different campuses into a single annual observation for the university. While most state medical schools share a single TLO with their state university, or at least share common policies, three state medical schools had independent policies and administration and had to be treated as separate institutions. Therefore, we also conducted separate analyses that omitted these three institutions. Our results did not change.

We confirmed the accuracy of the AUTM data in two ways. First, we conducted a search of the U.S. Patent and Trademark database to generate counts of university patents in each year from 1991-1998. We compared those counts to the counts reported by AUTM and found that they correlated at r=0.95. Second, we spoke to technology licensing officers at MIT, Georgia Tech, and Stanford University who confirmed that they have an incentive to report data accurately to AUTM and any discrepancies between AUTM data and actual numbers would be clerical errors.

Our sample captures almost all of the universities in our population. It incorporates over 90 percent of the top 100 US universities in terms of research and development expenditures and approximately 90 percent of the total number of university assigned patents. However, AUTM data is missing responses from some institutions from some years. Specifically, the AUTM data has complete records for 45 universities and is missing responses from all years for 6 universities.

We drop the six universities for which no data are available. The remaining institutions in our sample contain an average of 5.5 years of data.

We examine whether the universities that provide more data are different from those that provide less data and whether those that provide no data are different from those that provide some data. T-tests comparing important university attributes such as prestige scores, size of research program, number of invention disclosures, research revenue, and number of patents show no significant differences between universities missing panel observations and those not missing data. Similar tests between universities that did not send their data to AUTM and the general sample showed no significant differences on prestige and research funding. Moreover, we reran regression analyses with a dummy variable representing universities that were missing at least one year's data. This dummy variable was not significant. Thus, we believe that the reasons for missing data are idiosyncratic and unrelated to the factors that we measure in our study.

### Dependent Variable

The dependent variable in our analysis was the annual count of new technology licensing and option agreements established by the university. These data are provided by AUTM through their surveys of university technology licensing offices.

#### *Covariates*

<u>Prestige</u>. Our predictor variable is university prestige. Prestige arguments suggest that the behavior of potential licensees will be influenced by external perceptions of universities that are not necessarily directly linked to university's past performance at licensing. Our primary measure of prestige is the overall U.S. News and World Report graduate school ranking (1991-1998), a measure of the relative status ordering of different institutions as perceived by university presidents, deans and admissions directors.

U.S. News and World Report distributes questionnaires to college presidents, deans, and admissions directors throughout the U.S., and asks them to evaluate the prestige of other schools

by placing them into four quartiles. Four points were given for each vote in the top quartile, three for the second, two for the third, and 1 for the last category (U.S. News and World Report, September 30, 1991: 83). Universities were then placed in order of their scores and ranked against one another. Because some of the years were reported in ranks (1991-1997), while other years were reported using a scale (1997-1998), we converted the scores to ranks to make all years consistent.

To confirm the validity of the U.S. News and World Report ranking as a measure of university prestige, we also collected Gourman Report scores (Gourman, 1991; 1994; 1997), a commonly utilized measure of the overall intellectual prestige of the university's graduate programs as compared to other universities. The Gourman Report measures the collective assessment, relative to peer institutions, of the university's graduate programs in all fields, including the arts, humanities, social sciences, physical sciences, natural sciences, medicine, law, business, and engineering. University faculty and administrators are asked to rate universities' overall graduate program quality on 10 dimensions on a 1-5 scale. The Gourman Report staff also assesses the universities' strengths and weaknesses and assigns them an overall score. Because these scores are produced every three years, we update the Gourman Report measure in 1991, 1994, and 1997.

One of the advantages of using the Gourman Report measure in addition to the U.S. News and World Report measure is that the Gourman Report provides a score, while the U.S. News and World Report provides a ranking. By showing that we obtain the same results with a score as we did with a ranking, we can demonstrate that our results do not depend on constraining our analysis to comparisons within the sample.

As a final check, we also gathered data from the 1992 National Research Council (NRC) graduate department rankings. The NRC collects its data through a survey of graduate faculty at 3,634 programs around the country, who are asked to rank programs in their field (National Research Council, 1995).

Compared to the Gourman Report ratings and U.S. News and World Report rankings, the NRC rankings have the disadvantage of being gathered only once per decade. However, the NRC has the advantage of ranking specific departments on a 1 to 5 scale. This specificity allows us to create separate scores for departments that create patentable technologies (e.g., biology) and those that do not (e.g., history). For each university, we averaged the scores of the arts, humanities, social, and behavioral sciences to create the non-technical measure, and averaged the engineering, physical science, mathematics, and biological science scores to create the technical-measure.

All three measures capture university prestige because they are not tightly coupled with past licensing performance. It is very unlikely that the respondents to U.S. News and World Report, the Gourman Report, or NRC surveys were aware of the particulars of each university's past performance at licensing, and even less likely that they would use that criteria to rate the general prestige of the university.

The measures also demonstrate considerable convergent validity. U.S. News and World Report ranking had a 0.90 correlation with Gourman Report scores and a 0.86 correlation with NRC scores. Gourman Report scores also were highly correlated with the NRC scores (r = 0.85). We observed little change in the Gourman Report scores and the U.S. News and World Report rankings over the duration of the study. Correlations between measures for the years 1991-1998 were at least at the 0.88 level, with most years correlated above the 0.92 level. Correlations between values for adjacent years were strongest and deteriorated slightly over time.

<u>Past Performance</u>. The behavior of potential licensees should be influenced directly by the historical performance of the universities at technology licensing. However, past performance at licensing might be manifest in different ways. Potential licensees might pay particular attention to different indicators, such as the average level of licensing income generated per invention; the probability that an institution's inventions are worthy of license; the frequency with which past licenses yielded income; or the magnitude of the university's past licensing revenue. Therefore

we control for past performance with four different measures. All four measures are derived from data AUTM collected from the universities.

Past licensing revenues. Potential licensees might recognize that licensing is an inherently uncertain process in which a few inventions account for most of the licensing revenue. If potential licensees expect licensing revenue to be generated from a small number of successful licenses, then the total royalties generated from licensing at an institution will capture past performance. Therefore, we measure the total revenue generated from royalties on licensed inventions in the previous year. We expect that this variable will positively influence the current rate of licensing.

Past licensing yield. Potential licensees might recognize that only some university inventions are of interest to the private sector. If potential licensees expect that institutions will vary on the degree to which they produce technologies that appeal to the private sector, then the licensing yield may be an important signal to potential buyers. Therefore, we measure the proportion of invention disclosures in the past year that result in licenses. To create this variable, we divide the number of licenses issued in the past year by the number of inventions disclosed in that year. Licensing should be higher from universities whose past licensing yield is higher.

Past number of licenses yielding income. Potential licensees might recognize that not all licenses yield income. If potential licensees expect that institutions will vary in the degree to which they produce commercialized technologies, then the number of licenses yielding income will be an important indicator of past performance. Therefore, we measure the count of licenses yielding income in the past year. Licensing should be higher from universities that have more past licenses yielding income.

Average licensing revenue. Potential licensees might view the average performance of licenses at a particular university as the appropriate measure of past licensing performance. If this were the case, then the average amount of licensing revenue per license would make a licensor more appealing to potential buyers. Therefore, we measure the average revenue per

license in the past year. Licensing should be higher from universities that generate inventions of higher average value.

<u>Level of technology production</u>. Because the volume of technology produced will influence a university's rate of licensing, we control for the volume of technology available for licensing. We capture this effect by measuring the number of invention disclosures that the university produces in the year under investigation. The universities provided these data to AUTM.

<u>Technology licensing office resources</u>. Universities often hire personnel to market their inventions to private sector firms. Because technology-licensing officers have limited time, the effort that they can put into marketing a given invention is a function of the total number of inventions that they must handle. To capture this resource effect, we control for the number of invention disclosures per professional staff member in the university-year. We expect an inverse relationship between the number of disclosures per professional staff member and the number of licenses created in a university-year. The universities provided these data to AUTM.

As an alternative operationalization of licensing office resources, we also examined the absolute number of professional staff. However, we found it to be a proxy for the size of the university technical research program and, thus, highly correlated with the number of invention disclosures (r= 0.85). Moreover, we find that this measure has no effect in the regression analysis (most likely due to collinearity), but that the ratio of number of inventions to staff does. Because the former measure explains much of the same variance as the number of invention disclosures and does not have an effect, we report the regressions that show the ratio of inventions to staff.

<u>Source of funding</u>. Inventions are an outgrowth of investment in research. Government agencies or the private sector can fund university research. Prior research suggests that universities that receive more of their funding from the private sector generate more commercially-useful inventions than universities that receive more of their funding from the public sector because private firms have commercial goals for funding university research (Henderson et al, 1998). To capture the commercial orientation of university research, we

measure the proportion of university research funded by private sector firms in the previous year. We expect that universities that receive a greater share of funding from the private sector will have a greater number of licenses. We obtained these data from AUTM.

<u>Medical School</u> Researchers have observed that biomedical inventions are more likely to be patented and licensed by universities than are other inventions (Mowery et al, 2001). For this reason, we expect that universities with medical schools will have a higher rate of licensing than universities without medical schools. We control for this effect with a dummy variable of one if the university operates a medical school. We gathered these data from a search of university web sites.

<u>Geography.</u> We control for two attributes of the university's location: The level of private sector high technology activity in the area and the density of universities that license technology. Universities are more likely to license technology to firms located geographically close to them because the transfer of university technology often requires face-to-face contact (Mansfield, 1998). Because proximity to high technology firms should make universities more likely to license their technology, we controlled for the amount of high technology employment in the county in which the university was located. We use the county rather than the metropolitan statistical area because some of the universities we examine have rural locations and do not belong to a metropolitan statistical area.

Following Hecker (1999), we defined high technology industries as those in which research and development employment is at least twice the average for all industries. Using the Bureau of Labor Statistics annual survey, we created an annual measure of the total number of employees in high technology industries in each of the counties in which a university was located. As an alternative operationalization of local private sector technology activity, we measured the number of high technology organizations in the area, but it was not significant. Therefore, we report the regressions with the measure of high technology employment. A second effect of location could be that of competition between universities marketing technology to local firms. Because we would expect that institutions located in areas with a higher population of technology producing universities would face a higher degree of competition for potential licensees, we also control for the number of universities who are members of AUTM and are located within the same county as the focal institution.

Year. Invention and licensing activity varies over time as a function of various perturbations in the external environment. Therefore, we include year dummy variables to control for the time period (1992 is the omitted year).

#### Model Specification

Our model estimates the variation in annual license counts per university across a seven-year panel. Our explanatory variables are a mixture of continuous and discrete variables. We used generalized estimating equations (GEE) with a negative binomial distribution and a log linear link function to estimate the regressions (Liang and Zeger, 1986).

Pooling multiple observations over time for each organization increases the likelihood that cross sectional autocorrelation (general factors that characterize a particular university influence the behavior of the university at all points in time) will bias parameter estimates. In GEE models, one can correct for this autocorrelation by specifying the association among observations from each subject over time (Diggle, Liang, and Zeger, 1994). We specified a first order autoregressive pattern (AR1) because examination of the data revealed that observations closest in time had higher correlations than those more temporally distant.

To reduce problems associated with heteroskedasticity or misspecification of the error structure, we used robust variance estimators in our analyses (White, 1981). We also included a number of university level controls (technology licensing office staffing, research funding, number of invention disclosures, and existence of a medical school) to limit problems related to repeated observations.

We do not employ fixed effects models to analyze our data for methodological reasons. Typical fixed effects models for panel data cannot estimate effects for samples that include respondents for which there is no variation in the dependent variable over time. Approximately 10 percent of our sample falls into this category. Because universities that have no licensing activity over the observation period may be systematically different from those in which there was some licensing activity, dropping those observations (and thereby enabling the use of fixed effects models) would likely bias the estimates in the regression analysis. Estimating our regressions using a general estimating equation with an AR1 correlation structure enabled us to include universities that did not license technology during the observation period, without invoking the random effects assumption that errors are uncorrelated between years (STATA, 1999).

Because we seek to separate the portion of our predictor variable that captures variation in technology production capability from that which relates to prestige alone, we conduct two residual analyses. The first residual analysis, shown in Tables 4 and 5, uses U.S. News and World Report rankings and Gourman Report scores residualized on measures of past licensing performance. We generated this measure by regressing U.S. News and World Report rankings and the Gourman Report scores on the each of the four measures of past performance (in different analyses) and using the residuals from these analyses as measures of prestige in Tables 4 and 5. To the extent that our measures of prestige represent actual licensing capability, then past performance and U.S. News and World Report rankings and the Gourman Report scores should be closely correlated. Thus, separated from the performance component, the residualized measures of prestige capture that portion of prestige unrelated to past licensing performance.

Our second residual analysis incorporates information from Gourman Report engineering scores and is shown in Table 6. The ranking of non-technical areas cannot represent actual invention capability because these areas do not invent technology. Therefore, the overall ranking, stripped of the engineering program effect, more directly represents prestige effects unrelated to

licensing performance, and provides a more precise test of our arguments. Because engineering is one of the major sources of inventions in a university, the ranking of engineering programs provides a good proxy for an institution's technology ranking. To test this effect, in Table 6, we regress the overall rating on the engineering school scores and then use the residual values in the regression models that include the engineering school scores. We recognize that a better proxy would also include other fields that produce licensable inventions in the technology ranking. However, Gourman Report data were available only for engineering departments. For this reason we use the NRC data to parcel out technical and non-technical prestige effects in other regressions.

## Results

We provide the summary statistics for the variables in our regression analysis in Table 1. Table 2 presents estimates of the number of university licenses produced in a given year. Model 1 measures past performance as the university's average amount of licensing revenue per active license in the previous year. Model 2 measures past performance as the university's yield of licenses per invention disclosure in the previous year. Model 3 measures past performance as the magnitude of the university's licensing revenue in the previous year. Model 4 measures past performance as the number of university licenses yielding income in the previous year. Finally, Model 5 combines the four measures of past performance in a single model.

In order to increase the ease of interpretation, all results are reported as incidence rate ratios. Incident rate ratios can be interpreted as the percentage change in the dependent variable with a one-unit change in the independent variables. A ratio of one signifies no change, a ratio less than one indicates a negative relationship, and a ratio greater than 1 indicates a positive relationship.

Table 2 shows that the university's general prestige increases its rate of licensing, controlling for the volume of invention disclosures, the regional amount of high technology activity, the number of universities within a county, the source of university funding, the presence or absence of a medical school, the year, and the university's past licensing performance. Depending on which measure of past performance we controlled for in the regression models, a one unit increase in the U.S. News and World Report ranking increased the rate of licensing by approximately 1.5 percent.

Several of the control variables were also significant. Density of licensing universities in an area and the number of disclosures per professional staff decreased the rate of licensing, while the number of invention disclosures increased the rate of licensing. Consistent with our earlier arguments, the negative effect of density of licensing universities indicates competition for licensees between co-located universities. The negative effect of the number of disclosures per professional staff indicates the adverse effect of managing a high volume of technology on the ability of licensing officers to interest private sector firms in university technology. The positive effect of the number of disclosures indicates the positive effect of the quantity of technology available on licensing rates.

Table 3 provides a robustness check of the results presented in Table 2 by substituting the Gourman Report scores for the U.S. News and World Report rankings. The results shown in Table 3 confirm the prior results. Depending on which measure of past performance was controlled; a one-unit increase in the Gourman Report scores increased the rate of licensing around 75 percent. (The coefficients for the Gourman Report scores and the U.S. News and World Report rankings differ in magnitude because they are measured in very different ways. An increase of one unit has a different meaning in the two measures.)

Tables 4 and 5 provide a second robustness check by substituting U.S. News and World Report rankings and Gourman Report scores residualized on past performance for the non-residualized scores. The results in Tables 4 and 5 corroborate those in Table 2. The residualized prestige scores have a positive and significant effect on the rate of licensing in all models.

Table 6 provides a third robustness check by adding the Gourman Report scores for engineering programs to the models shown in Table 2. The residualized Gourman Report score

has a positive effect, indicating that the prestige of the university influences a university's ability to license, even after past performance and engineering department rankings are controlled.

Table 7 provides our final robustness check. In this table we use the National Research Council's ratings of university programs to measure prestige. The NRC data allows us to measure both technical and non-technical fields. Because non-technical areas of the university have no direct effect on the university's inventive capability, any positive effect of the nontechnical areas on licensing rates, controlling for the technical area score, have to be attributed to prestige.

The measures of technical and non-technical departments were highly correlated, so we orthogonalized them on one another and on the measure of quality corresponding to each model (Saville and Wood, 1991). Because we are orthogonalzing several variables, we used a modified Gram-Schmidt procedure (Golub and Van Loan, 1989; Partlett and Scott, 1979). This technique can be viewed as a process of subtracting the vector from its projection, resulting in orthogonal variables. The interpretation of the orthogonalized variable is the independent variable in question minus the linear influences of the variables upon which it is orthogonalized. In our case, one can interpret the non-technical score as that part of prestige that is not explained by the technical score or past performance.

The results shown in Table 7 indicate that the NRC scores for non-technical departments are significant predictors of licensing rates after controlling for past performance at licensing, the scores for technical departments, and the other controls are included in the regression equations. Thus, the results shown in Table 7 also support our hypothesis: university prestige increases the rate of licensing over that expected from past performance at licensing.

## Discussion

This study examined why some universities license more of their inventions than other universities over the 1991-1998 period. We showed how general university prestige increases the licensing rate over that predicted by past performance. We also showed that this prestige effect occurs after controlling for the amount of technology produced by the university, the source of research funding, the presence or absence of a medical school, the geographic location of the university, and the resources of the technology licensing office. Moreover, this remained true across several measures of prestige, and after controlling for the rankings of engineering and other technical programs.

Our results support an important distinction between economic and sociological assumptions about how perceptions influence inter-organizational transactions. Economic arguments propose a tight coupling between past performance and current demand (Kreps and Wilson, 1982), whereas sociological conceptions of prestige accept a looser coupling of these two forces. By demonstrating that prestige has an effect on market transactions over and above the effects of past performance, this study provides evidence of the loose coupling between past performance and demand suggested by sociologists and organizational theorists (Podolny, 1993).

Differentiating between loose and tight coupling of past performance and demand is important because the strength of that coupling influences the breadth of the effect of external perceptions of organizations. Because economic theories argue that external perceptions of organizations are narrow in scope and tightly coupled to their past performance, these arguments hold that actors can use external perceptions to influence market transactions only in similar settings. However, theories of prestige argue that external perceptions and past performance are loosely coupled, allowing actors to transfer external perceptions across domain barriers. For example, a university can use the overall external perceptions that accrue from a variety of highly ranked non-technical departments (such as English, history, etc.) to license more of its inventions.

A second major implication of our results is that prestige helps to overcome problems of market failure, extending research on the social embeddedness of market transactions in a new direction. Prior research (Granovetter, 1985; Bradach and Eccles, 1988; Powell, 1990) has argued that social ties between actors help to overcome the problems inherent in market transactions. Because social ties enhance trust and facilitate information transfer, they overcome

information problems that undermine market-based transactions. Unlike past research on social ties, this study supports a different stream of research on the social embeddedness of markets. Similar to Podolny (1994), our results demonstrate that, under conditions of uncertainty, people often use prestige to make decisions. Because the mechanism through which prestige influences market transactions is different from that of social ties, this study suggests the importance of examining prestige (as well as social ties) to correct under-socialized views of market transactions.

The third major implication of our results is to extend prestige effects to markets for knowledge. Arrow (1962) explained that markets for knowledge-based assets are plagued by problems of uncertainty, indivisibility, and inappropriability. Yet, markets for knowledge are facilitated by prestige. Although organizational theorists have often viewed economic arguments for market failure as under-socialized, they have undertaken little investigation of social mechanisms, like prestige, that overcome failure in markets for knowledge. Because these assets are increasingly important, the absence of research concerning how prestige facilitates knowledge transfer in markets is an important void in organizational conceptions of market behavior.

The fourth major implication of our study has been to provide an organizational explanation for university technology transfer. Although economists have been quick to develop theories to explain technology transfer in the post-Bayh-Dole era, few organizational theorists have sought to explain this phenomenon (an important exception is Etzkowitz [1998]). This study provides support for an organizational perspective on university technology transfer. Although economic studies of technology transfer assume that inventions with the best technical specifications are the ones that will be licensed from universities, this study is more in line with the logic of the sociology of technology (e.g., Podolny and Stuart, 1995), suggesting that technical attributes alone may be insufficient to explain the likelihood of transfer.

The evidence that prestigious universities are more successful at licensing technology is also consistent with several themes in the sociology of technology. It supports the thesis that technical outcomes are not only a function of objective attributes, but are also a function of the social context in which those activities are embedded (Granovetter, 1985; Podolny, 1994). In addition, it suggests the idea that technological evolution is socially constructed. As a result, a Matthew effect (Merton, 1968) might explain the higher performance of prestigious universities at technology licensing better than the argument that more prestigious universities produce better technology (Henderson et al, 1998). Prestigious universities may be better able to license their inventions than less prestigious universities not because the technologies that they produce are better ex-ante, but because the universities that produce them are perceived as more prestigious. Because increased revenues derived from licensing lead to greater likelihood of licensing and greater prestige in following years, over time, an initial prestige effect becomes embedded and strengthens status differentials in a circular flow of advantage to prestigious actors.

An important extension of this idea concerns the contribution of different universities to technical advance in industry. Because firms are more likely to invest in the development of licensed inventions than unlicensed ones, the exploitation of university technology by the private sector is enhanced by the prestige of the school transferring the technology. This pattern suggests that prestigious universities will have a disproportionate influence on the evolution of technology and industry, not because they are necessarily superior creators of technology, but because their prestige facilitates technology transfer. If more prestigious institutions are better able to diffuse knowledge than less prestigious institutions, then inventors from high prestige institutions and their research will have a disproportionate effect on technological change in society.

## Conclusion

This paper demonstrates that, over the period 1991-1998, university prestige increased the rate at which U.S. universities licensed their inventions above the rate predicted by the universities' past licensing performance. By demonstrating empirical support for the effect of prestige over and above the university's past licensing performance, the source of research funding, their rate of invention production, and the resources of the technology licensing offices,

these findings extend the arguments of sociologists and organizational theorists for prestige effects in market transactions. We hope that these results encourage future researchers to consider the importance of prestige as a mechanism to overcome market failure, particularly in the context of markets for knowledge.

#### References

- Adams, J. 1990. Fundamental stocks of knowledge and productivity growth. *Journal of Political Economy*, 98: 673-702.
- Allen, F. 1984. Reputation and product quality. Rand Journal of Economics, 15(3): 305-327.
- Allison, P. D., & Long, P. D. 1990. Departmental effects on scientific productivity. American Sociological Review, 55(4): 469-478.
- Arrow, K. 1962. Economic welfare and the allocation of resources for invention. In R. Nelson (ed.), *The Rate and Direction of Inventive Activity*. Princeton: Princeton University Press.
- Arrow, K. 1974. The Limits of Organization. New York: W.W. Norton.
- Asch, S. 1940. Studies in the principles of judgments and attitudes II: Determination of judgments by group and by ego standards. *Journal of Social Psychology*, 12: 433-465.
- Association of University Technology Managers. 1999. *AUTM Licensing Survey*. Norwalk: Association of University Technology Managers.
- Benjamin, B., & Podolny, J. 1999. Status, quality and social order in the California wine industry. *Administrative Science Quarterly*, 44: 563-589.
- Bradach, J. L., & Eccles, R. G. 1989. Price, authority, and trust: from ideal types to plural forms. *Annual Review of Sociology*, 15: 97-118.
- Bray, M., and Lee, J. 2000. University revenues from technology transfer: Licensing fees vs. equity positions. *Journal of Business Venturing*, 15: 385-392.
- Cameron, A. C., & Trivedi, P. K. 1998. *Regression Analysis of Count Data*. Cambridge: The Press Syndicate of the University of Cambridge.
- Crane, D. 1965. Scientists at major and minor universities: a study of productivity and recognition. *American Sociological Review*, 30(5): 699-714.
- Diggle, P. L., Liang, K. Y., & Zeger, S. L. 1994. *Analysis of Longitudinal Data*. New York: Oxford University Press Inc.
- Etzkowitz, H. 1998. The norms of entrepreneurial science: Cognitive effects of the new university-industry linkages. *Research Policy*, 27: 823-833.
- Feldman, M., Feller, I., Bercovitz, J., and Burton, R. 2002. Equity and the technology transfer strategies of American universities. *Management Science*.
- Golub, G.H. and C. F. Van Loan. 1989. *Matrix Computations*, Baltimore: Johns Hopkins University Press.

Gourman, J. 1991. The Gourman Report. Northridge, CA: National Education Standards.

Gourman, J. 1994. The Gourman Report. Northridge, CA: National Education Standards.

Gourman, J. 1997. The Gourman Report. Northridge, CA: National Education Standards.

- Granovetter, M. 1985. Economic action and social structure: The problem of embeddedness. *American Journal of Sociology*, 91: 481-510.
- Hecker, Daniel. 1999. High technology employment: A broader view. *Monthly Labor Review*, 122 (6): 18-30.
- Henderson, R., Jaffe, A., & Trajtenberg, M. 1998. Universities as a source of commercial technology: A detailed analysis of university patenting, 1965-1988. *Review of Economics* and Statistics, 65: 119-127.
- Hovland, C., Janis, I., & Kelly, H. 1953. *Communication and Persuasion*. New Haven, CT: Yale University Press.
- Jaffe, A. 1989. Real effects of academic research. American Economic Review, 79(5): 957-970.
- Kreps, D., & Wilson, R. 1982. Reputation and imperfect information. *Journal of Economic Theory*, 27: 253-279.
- Lewin, K. 1935. Dynamic Theory of Personality. New York: McGraw-Hill.
- Liang, K., and Zeger, S. 1986. Longitudinal data analysis using generalized linear models. *Biometrika*, 73(1): 13-22.
- Mansfield, E. 1998. Academic research and industrial innovation: An update of empirical findings. *Research Policy* 26: 773-776.
- Merton, R. 1968. The Matthew effect in science. Science, 159: 56-63.
- Minnis, M. S. 1953. Cleavage in women's organizations: a reflection of the social structure of a city. *American Sociological Review*, 18(1): 47-53.
- Mowery, D. C., Nelson, R. R., & Ziedonis, B. N. S. A. A. 2001. The growth of patenting and licensing by US universities: an assessment of the effects of the Bayh-Dole act of 1980. *Research Policy*, 30(1): 99-119.
- National Research Council. 1995. *Research-Doctorate Programs in the United States Continuity and Change*. Washingtion D.C.: National Academy of Sciences.
- Parsons, T. 1951. Essays in Sociological Theory. Glencoe, IL: The Free Press.
- Parlett, B. N. & Scott, D. S: 1979, The Lanczos Algorithm with Selective Orthogonalization'. *Mathematics of Computation* 33(145): 217-238
- Perrow, C. 1961. Organizational prestige: some functions and dysfunctions. *American Journal* of Sociology, 66(4): 335-341.
- Podolny, J. 1993. A status-based model of market competition. *American Journal of Sociology*, 98(4): 829-872.

- Podolny, J. 1994. Market uncertainty and the social character of economic exchange. *Administrative Science Quarterly*, 39: 458-483.
- Podolny, J., & Stuart, T. 1995. A role-based ecology of technological change. *American Journal of Sociology*, 100: 1224-1260.
- Powell, W. 1990. Neither market nor hierarchy: Network forms of organization. *Research in Organizational Behavior*, 12: 295-336.
- Rosenberg, N., & Nelson, R. 1994. American universities and technical advance in industry. *Research Policy*, 23: 323-348.
- Saville, D. & Wood, G. R. (1991). *Statistical Methods: The Geometric Approach*. New York: Springer-Verlag.
- Shenkar, O., & Yuchtman-Yaar, E. 1997. Reputation, image, prestige, and goodwill: an interdisciplinary approach to organizational standing. *Human Relations*, 50: 1361-1381.
- Shrum, W., & Wuthnow, R. 1988. Reputational status of organizations in technical systems. *American Journal of Sociology*, 93(4): 882-912.
- StataCorp. 1999. Stata Statistical Software: Release 6.0. College Station, TX: Stata Corporation.
- Stuart, T. 1998. Network positions and propensities to collaborate: An investigation of strategic alliance formation in a high-technology industry. *Administrative Science Quarterly*, 43: 668-698.
- Tallman, S., & Shenkar, O. 1996. A decision-making model of international cooperative venture formation. *Journal of International Business Studies*, 69: 91-113.
- U. S. News & World Report. 1991-1998. *America's Best Colleges*. Washington DC: U. S. News & World Report.
- Weigelt, K., & Camerer, C. 1988. Reputation and corporate strategy: A review of recent theory and applications. *Strategic Management Journal*, 9(5): 443-454.
- White, H. 1981. Where do markets come from? American Journal of Sociology, 87: 517-547.
- Wilson, R. 1985. Reputations in games and markets. In A. Roth (ed.), *Game Theoretic Models* of *Bargaining*: 65-84. New York: Cambridge University Press.
- Young, R. C., & Larson, O. F. 1965. The contribution of voluntary organizations to community structure. *American Journal of Sociology*, 71(2): 178-186.

Variable	1	2	3	4	5	6	7	8	9	10	11
Mean	38.29	0.41	71.05	27.12	4.11	3.77	0.11	0.60	20.35	2.71	2.83
Standard Deviation	70.93	0.84	82.10	24.91	0.51	0.78	0.09	0.49	26.92	0.72	0.76
Minimum	0.00	0.00	0.00	0.00	3.11	2.01	0.00	0.00	0.00	0.98	0.92
Maximum	577.00	3.00	742.00	250.00	4.94	4.95	0.56	1.00	191.00	4.42	4.64
1. Density of High Tech Employees*	1.00										
2. Density of Licensing Universities	-0.16	1.00									
3. Invention Disclosures	0.72	-0.21	1.00								
4. Disclosures per Professional Staff	0.16	-0.10	0.21	1.00							
5. Gourman Engineering Scores	0.45	-0.22	0.56	0.23	1.00						
6. Gourman Scores	0.35	-0.06	0.46	0.12	0.75	1.00					
7. Industry Funding Ratio	-0.15	-0.02	-0.12	-0.01	-0.17	-0.27	1.00				
8. Medical School	0.11	0.22	0.13	-0.13	0.08	0.37	-0.18	1.00			
9. Number of licenses	0.53	-0.20	0.75	-0.09	0.52	0.45	-0.15	0.18	1.00		
10. NRC Non-technical Scores	0.40	-0.13	0.49	0.06	0.66	0.83	-0.26	0.31	0.50	1.00	
11. NRC Technical Scores	0.44	-0.26	0.54	0.17	0.79	0.84	-0.24	0.16	0.53	0.88	1.00
12. Past Licenses / Disclosures	0.00	-0.03	-0.07	-0.23	0.07	0.14	-0.06	0.08	0.31	0.17	0.16
13. Past Licenses Yielding Income	0.64	-0.17	0.78	-0.12	0.45	0.40	-0.11	0.13	0.79	0.46	0.47
14. Past Licensing Revenue/Year**	0.01	0.31	-0.03	0.02	-0.02	0.00	-0.02	0.04	-0.01	-0.09	-0.10
15. Past Licensing Revenue**	0.62	-0.03	0.65	-0.10	0.35	0.31	-0.10	0.17	0.69	0.35	0.34
16. U.S.News & World Report Rank	-0.32	0.06	-0.41	-0.13	-0.72	-0.90	0.22	-0.31	-0.43	-0.88	-0.86
17. 1993	0.02	0.03	-0.01	-0.04	0.05	0.05	0.08	0.03	-0.04	0.06	0.06
18. 1994	0.00	0.00	-0.05	0.00	-0.02	-0.01	-0.02	0.01	-0.03	0.01	0.00
19. 1995	-0.01	-0.02	-0.03	0.00	-0.03	-0.03	0.02	-0.02	-0.03	-0.04	-0.04
20. 1996	0.00	-0.01	0.00	0.04	-0.04	-0.03	0.00	-0.02	-0.01	-0.04	-0.03
21. 1997	-0.01	0.01	0.06	0.04	0.00	0.00	-0.01	0.02	0.06	-0.01	-0.01
22. 1998	-0.02	-0.02	0.06	-0.02	0.01	-0.01	-0.02	-0.04	0.11	-0.03	-0.02

Table 1. Correlations and Summary Statistics

\*Thousands of employees \*\*Millions of Dollars

Variable	12	13	14	15	16	17	18	19	20	21	22
Mean	0.31	41.87	73.20	2.79	50.63	0.13	0.13	0.13	0.13	0.13	0.13
Standard Deviation	0.34	70.67	162	7.36	31.13	0.33	0.33	0.33	0.33	0.33	0.33
Minimum	0.00	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
Maximum	5.89	763	2718	67.28	108	1.00	1.00	1.00	1.00	1.00	1.00
12. Past Licenses / Disclosures	1.00										
13. Past Licenses Yielding Income	0.14	1.00									
14. Past Licensing Revenue/Year**	-0.03	0.00	1.00								
15. Past Licensing Revenue**	0.09	0.78	0.29	1.00							
16. U.S.News & World Report Rank	-0.18	-0.36	0.03	-0.27	1.00						
17. 1993	0.10	-0.03	0.03	-0.04	-0.06	1.00					
18. 1994	0.03	-0.06	-0.04	-0.04	0.01	-0.16	1.00				
19. 1995	-0.02	-0.04	0.01	-0.02	0.05	-0.17	-0.19	1.00			
20. 1996	-0.04	0.01	-0.05	-0.01	0.03	-0.16	-0.18	-0.19	1.00		
21. 1997	-0.02	0.06	0.01	0.05	0.00	-0.15	-0.17	-0.18	-0.17	1.00	
22. 1998	0.01	0.13	0.04	0.12	0.02	-0.16	-0.17	-0.19	-0.18	-0.17	1.00

Table 1. Correlations and Summary Statistics Continued

\*Thousands of employees \*\* Millions of Dollars

Mariahla	Model							
variable	1 <sup>a,b</sup>	2 <sup>a,b</sup>	3 <sup>a,b</sup>	4 <sup>a,b</sup>	5 <sup>a,b</sup>			
Density of High Tech	0.998	0.998	0.998	0.998	0.998			
Employees	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]			
Density of Licensing	0.879*	0.885+	0.878+	0.895+	0.881*			
Universities	[0.057]	[0.056]	[0.059]	[0.058]	[0.051]			
Disclosures of Inventions	1.006**	1.006**	1.006**	1.005**	1.005**			
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]			
Disclosures per	0.996*	0.995*	0.996*	0.997	0.996+			
Professional Staff	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]			
Industry Funding Ratio	0.716	0.795	0.739	0.771	0.722			
	[0.338]	[0.349]	[0.356]	[0.371]	[0.319]			
Medical School	1.174	1.182	1.236	1.254	1.174			
	[0.179]	[0.176]	[0.197]	[0.192]	[0.152]			
Licensing Revenue/Year <sup>c</sup>	1.080+				1.107*			
0	[0.043]				[0.049]			
Past Licenses /		1.058**			1.069**			
Disclosures <sup>c</sup>		[0.010]			[0.017]			
Past Licensing Revenue			1.015*		0.995			
(In Millions of Dollars)			[0.007]		[0.008]			
Past Licenses Yielding				1.003+	1.003*			
Income				[0.001]	[0.002]			
U.S. News and World	1.015**	1.014**	1.015**	1.015**	1.012**			
Report Ranking	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]			
1993	1.254*	1.230*	1.247*	1.230*	1.221*			
	[0.117]	[0.125]	[0.123]	[0.125]	[0.120]			
1994	1.422**	1.339**	1.395**	1.366**	1.316**			
	[0.124]	[0.112]	[0.124]	[0.125]	[0.117]			
1995	1.343**	1.293**	1.337**	1.335**	1.239**			
	[0.094]	[0.094]	[0.098]	[0.106]	[0.095]			
1996	1.299**	1.251**	1.287**	1.242*	1.189+			
	[0.110]	[0.107]	[0.113]	[0.116]	[0.116]			
1997	1.481**	1.462**	1.476**	1.411**	1.340**			
	[0.142]	[0.136]	[0.145]	[0.156]	[0.149]			
1998	1.539**	1.566**	1.529**	1.460**	1.366*			
	[0.161]	[0.152]	[0.176]	[0.188]	[0.184]			
Observations	521	534	537	535	516			
	95	97	97	97	95			
Uni Squared Statistic	362.55	507.59	386.65	405.54	572.21			

Table 2. Negative binomial estimation of the annual count of university technology licenses using the U.S. News and World Report Rankings as a measure of prestige.

<sup>a</sup>The results are reported as incidence rate ratios <sup>b</sup> AR1 correlation Structure

<sup>c</sup> Log transformation

Mastable	Model						
Variable	1 <sup>a,b</sup>	2 <sup>a,b</sup>	3 <sup>a,b</sup>	4 <sup>a,b</sup>	5 <sup>a,b</sup>		
Density of High Tech	0.998	0.998	0.998	0.998	0.998		
Employees	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]		
Density of Licensing	0.876*	0.887+	0.877+	0.895+	0.882*		
Universities	[0.059]	[0.058]	[0.060]	[0.060]	[0.053]		
Invention Disclosures	1.006**	1.007**	1.006**	1.006**	1.006**		
	[0.002]	[0.002]	[0.001]	[0.001]	[0.001]		
Disclosures per	0.996*	0.995*	0.996*	0.997+	0.996+		
Professional Staff	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]		
Industry Funding Ratio	0.777	0.726	0.749	0.788	0.778		
	[0.412]	[0.413]	[0.414]	[0.438]	[0.375]		
Medical School	1.142	1.151	1.200	1.219	1.154		
	[0.169]	[0.170]	[0.185]	[0.181]	[0.144]		
Licensing Revenue/Year <sup>c</sup>	1.095*				1.121**		
	[0.044]				[0.050]		
Past Licenses /		1.038**			1.072**		
Disclosures <sup>c</sup>		[0.012]			[0.015]		
Past Licensing Revenue			1.018*		0.995		
(In Millions of Dollars)			[0.008]		[0.009]		
Past Licenses Yielding				1.003+	1.003*		
Income				[0.002]	[0.002]		
Gourman Report Scores	1.723**	1.730**	1.752**	1.726**	1.565**		
	[0.161]	[0.155]	[0.151]	[0.147]	[0.139]		
1993	1.275**	1.270*	1.282**	1.262*	1.230*		
	[0.112]	[0.123]	[0.121]	[0.124]	[0.115]		
1994	1.432**	1.375**	1.414**	1.382**	1.320**		
	[0.122]	[0.112]	[0.119]	[0.121]	[0.115]		
1995	1.308**	1.256**	1.298**	1.299**	1.208*		
	[0.092]	[0.093]	[0.097]	[0.106]	[0.094]		
1996	1.270**	1.225*	1.261**	1.217*	1.161		
4007	[0.108]	[0.104]	[0.113]	[0.117]	[0.116]		
1997	1.416**	1.400**	1.412**	1.353**	1.287*		
4000	[0.135]	[0.124]	[0.138]	[0.147]	[0.144]		
1998	1.508**	1.537**	1.503**	1.437***	1.332"		
Observations	[0.162]	[0.154]	[0.185]	[0.194]	[0.186]		
Number of Sebools	549	567	570	568	544		
Chi Squared	100	103	103	103	100		
Uni Squared	383.69	463.15	417.09	431.92	630.35		

Table 3. Negative binomial estimation of the annual count of university technology licenses using the Gourman Report scores as a measure of prestige.

<sup>a</sup>The results are reported as incidence rate ratios <sup>b</sup> AR1 correlation Structure

<sup>c</sup> Log transformation

Veriable	Model							
Variable	1 <sup>a,b</sup>	2 <sup>a,b</sup>	3 <sup>a,b</sup>	4 <sup>a,b</sup>				
Density of High Tech	0.998	0.998	0.998	0.998				
Employees	[0.001]	[0.001]	[0.001]	[0.001]				
Density of Licensing	0.879*	0.885+	0.878+	0.895+				
Universities	[0.057]	[0.056]	[0.059]	[0.058]				
Invention Disclosures	1.006**	1.006**	1.006**	1.005**				
	[0.001]	[0.001]	[0.001]	[0.001]				
Disclosures per	0.996*	0.995*	0.996*	0.997				
Professional Staff	[0.002]	[0.002]	[0.002]	[0.002]				
Industry Funding Ratio	0.716	0.795	0.739	0.771				
	[0.338]	[0.349]	[0.356]	[0.371]				
Medical School	1.174	1.182	1.236	1.254				
	[0.179]	[0.176]	[0.197]	[0.192]				
Licensing Revenue/Year <sup>c</sup>	1.175**							
C C	[0.049]							
Past Licenses /		1.090**						
Disclosures <sup>c</sup>		[0.011]						
Past Licensing Revenue			1.033**					
(In Millions of Dollars)			[0.008]					
Past Licenses Yielding				1.006**				
Income				[0.001]				
Residualized Measure of	1.015**	1.014**	1.015**	1.015**				
the U.S. News and World Report Ranking	[0.002]	[0.002]	[0.002]	[0.002]				
1993	1.254*	1.230*	1.247*	1.230*				
	[0.117]	[0.125]	[0.123]	[0.125]				
1994	1.422**	1.339**	1.395**	1.366**				
	[0.124]	[0.112]	[0.124]	[0.125]				
1995	1.343**	1.293**	1.337**	1.335**				
	[0.094]	[0.094]	[0.098]	[0.106]				
1996	1.299**	1.251**	1.287**	1.242*				
	[0.110]	[0.107]	[0.113]	[0.116]				
1997	1.481**	1.462**	1.476**	1.411**				
	[0.142]	[0.136]	[0.145]	[0.156]				
1998	1.539**	1.566**	1.529**	1.460**				
	[0.161]	[0.152]	[0.176]	[0.188]				
Observations	521	534	537	535				
Number of Schools	95	97	97	97				
Chi Squared Statistic	362.55	507.59	386.65	405.54				

**Table 4.** Negative binomial estimation of the annual count of university technology

 licenses using the residualized measure of the U.S. News and World Report Rankings.

<sup>a</sup>The results are reported as incidence rate ratios

<sup>b</sup> AR1 correlation Structure

<sup>c</sup> Log transformation

**Table 5.** Negative binomial estimation of the annual count of university technologylicenses using the residualized measure of the Gourman Report scores.

Variable	Model								
variable	1 <sup>a,b</sup>	<b>2</b> <sup>a,b</sup>	3 <sup>a,b</sup>	4 <sup>a,b</sup>					
Density of High Tech	0.998	0.998	0.998	0.998					
Employees	[0.002]	[0.002]	[0.002]	[0.002]					
Density of Licensing	0.876*	0.887+	0.877+	0.895+					
Universities	[0.059]	[0.058]	[0.060]	[0.060]					
Invention Disclosures	1.006**	1.007**	1.006**	1.006**					
	[0.002]	[0.002]	[0.001]	[0.001]					
Disclosures per	0.996*	0.995*	0.996*	0.997+					
Professional Staff	[0.002]	[0.002]	[0.002]	[0.002]					
Industry Funding Ratio	0.777	0.726	0.749	0.788					
	[0.412]	[0.413]	[0.414]	[0.438]					
Medical School	1.142	1.151	1.200	1.219					
	[0.169]	[0.170]	[0.185]	[0.181]					
Licensing Revenue/Year <sup>c</sup>	1.204**								
	[0.047]								
Past Licenses /		1.064**							
Disclosures <sup>c</sup>		[0.013]							
Past Licensing Revenue			1.037**						
(In Millions of Dollars)			[0.008]						
Past Licenses Yielding				1.006**					
Income				[0.002]					
Residualized Measure of	1.723**	1.730**	1.752**	1.726**					
the Gourman Report	[0.161]	[0.155]	[0.151]	[0.147]					
Scores									
1993	1.275**	1.270*	1.282**	1.262*					
	[0.112]	[0.123]	[0.121]	[0.124]					
1994	1.432**	1.375**	1.414**	1.382**					
	[0.122]	[0.112]	[0.119]	[0.121]					
1995	1.308**	1.256**	1.298**	1.299**					
	[0.092]	[0.093]	[0.097]	[0.106]					
1996	1.270**	1.225*	1.261**	1.217*					
	[0.108]	[0.104]	[0.113]	[0.117]					
1997	1.416**	1.400**	1.412**	1.353**					
	[0.135]	[0.124]	[0.138]	[0.147]					
1998	1.508**	1.537**	1.503**	1.437**					
	[0.162]	[0.154]	[0.185]	[0.194]					
Observations	549	567	570	568					
Number of Schools	100	103	103	103					
Chi Squared Statistic	383.69	463.15	417.09	431.92					

<sup>a</sup>The results are reported as incidence rate ratios

<sup>b</sup> AR1 correlation Structure

<sup>c</sup> Log transformation

Martalia	Model							
variable	1 <sup>a,b</sup>	<b>2</b> <sup>a,b</sup>	3 <sup>a,b</sup>	4 <sup>a,b</sup>				
Density of High Tech	0.998	0.998	0.998	0.998				
Employees	[0.001]	[0.001]	[0.001]	[0.002]				
Density of Licensing	0.848*	0.860*	0.850*	0.868+				
Universities	[0.062]	[0.064]	[0.064]	[0.065]				
Invention Disclosures	1.005**	1.005**	1.005**	1.004**				
	[0.001]	[0.001]	[0.001]	[0.001]				
Disclosures per Professional	0.996*	0.995*	0.996+	0.997				
Staff	[0.002]	[0.002]	[0.002]	[0.002]				
Industry Funding Ratio	0.698	0.874	0.743	0.805				
	[0.521]	[0.577]	[0.539]	[0.585]				
Medical School	1.139	1.137	1.156	1.171				
	[0.147]	[0.144]	[0.150]	[0.150]				
Licensing Revenue/Year <sup>c</sup>	1.095+							
	[0.056]							
Past Licenses / Disclosures <sup>c</sup>		1.047**						
		[0.013]						
Past Licensing Revenue (In			1.018*					
Millions of Dollars)			[0.008]					
Past Licenses Yielding				1.002				
Income				[0.002]				
Residualized measure of the	1.383*	1.386*	1.384*	1.379*				
Gourman Report Score	[0.218]	[0.208]	[0.218]	[0.211]				
Gourman Report Scores for	2.227**	2.260**	2.198**	2.181**				
Engineering Programs	[0.466]	[0.451]	[0.424]	[0.416]				
1993	1.212*	1.201	1.212+	1.206+				
	[0.117]	[0.137]	[0.131]	[0.134]				
1994	1.398**	1.343**	1.366**	1.362**				
	[0.132]	[0.123]	[0.130]	[0.134]				
1995	1.331**	1.297**	1.310**	1.330**				
	[0.098]	[0.103]	[0.102]	[0.110]				
1996	1.302**	1.253*	1.268*	1.240*				
	[0.119]	[0.113]	[0.120]	[0.126]				
1997	1.385**	1.382**	1.364**	1.327*				
	[0.147]	[0.130]	[0.142]	[0.154]				
1998	1.517**	1.562**	1.483**	1.442**				
	[0.178]	[0.167]	[0.189]	[0.199]				
Observations	447	448	450	448				
Number of Schools	80	80	80	80				
Chi Squared Statistic	358.19	436.45	355.21	389.75				

 
 Table 6. Negative binomial estimation of the annual count of university technology licenses
 using the residualized measure of Gourman Report general and engineering scores.

<sup>a</sup>The results are reported as incidence rate ratios <sup>b</sup> AR1 correlation Structure

<sup>c</sup> Log transformation

Verieble	Model							
variable	1 <sup>a,b</sup>	2 <sup>a,b</sup>	3 <sup>a,b</sup>	4 <sup>a,b</sup>				
Density of High Tech	0.948	0.956	0.958	0.967				
Employees	[0.052]	[0.048]	[0.055]	[0.053]				
Density of Licensing	0.883	0.887	0.869	0.860				
Universities	[0.072]	[0.069]	[0.079]	[0.084]				
Invention Disclosures	0.939	0.918+	0.932	0.944				
	[0.038]	[0.044]	[0.040]	[0.040]				
Disclosures per	0.996	0.997	0.996	1.003				
Professional Staff	[0.036]	[0.035]	[0.037]	[0.037]				
Industry Funding Ratio	1.179	1.191	1.231	1.254				
	[0.189]	[0.187]	[0.203]	[0.200]				
Medical School	1.365**	1.377**	1.385**	1.400**				
	[0.070]	[0.072]	[0.074]	[0.080]				
Licensing Revenue/Year <sup>c,d</sup>	1.071 [0.049]							
Past Licenses / Disclosures <sup>c,d</sup>		1.168** [0.047]						
Past Licensing Revenue <sup>d</sup> (In Millions of Dollars)			1.061 [0.041]					
Past Licenses Yielding Income <sup>d</sup>				1.105* [0.055]				
NRC Technical Department	1.955**	2.007**	1.946**	1.948**				
Rankings <sup>d</sup>	[0.110]	[0.118]	[0.107]	[0.108]				
NRC Non-Technical	1.398**	1.419**	1.401**	1.403**				
Department Rankings <sup>d</sup>	[0.066]	[0.065]	[0.065]	[0.063]				
1993	1.246*	1.237*	1.241*	1.228*				
	[0.107]	[0.116]	[0.113]	[0.115]				
1994	1.409**	1.369**	1.394**	1.374**				
	[0.116]	[0.110]	[0.115]	[0.117]				
1995	1.340**	1.322**	1.343**	1.347**				
	[0.088]	[0.097]	[0.094]	[0.104]				
1996	1.291**	1.273**	1.287**	1.248*				
	[0.106]	[0.108]	[0.111]	[0.118]				
1997	1.480**	1.501**	1.490**	1.429**				
	[0.139]	[0.139]	[0.142]	[0.155]				
1998	1.564**	1.627**	1.572**	1.501**				
	[0.171]	[0.166]	[0.188]	[0.204]				
Observations	505	514	516	514				
Number of Schools	91	92	92	92				
A Chi Squared Statistic	414.93	458.58	433.73	443.42				

 
 Table 7. Negative binomial estimation of the annual count of university technology
 licenses using the NRC measures of technical and non-technical programs.

<sup>a</sup>The results are reported as incidence rate ratios

<sup>b</sup> AR1 correlation Structure

<sup>c</sup> Log transformation <sup>d</sup> Measures are orthogonalized