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Why do some universities generate more start-ups than others?[☆]

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Abstract

The results of this study provide insight into why some universities generate more new companies to exploit their intellectual property than do others. We compare four different explanations for cross-institutional variation in new firm formation rates from university technology licensing offices (TLOs) over the 1994–1998 period—the availability of venture capital in the university area; the commercial orientation of university research and development; intellectual eminence; and university policies. The results show that intellectual eminence, and the policies of making equity investments in TLO start-ups and maintaining a low inventor's share of royalties increase new firm formation. The paper discusses the implications of these results for university and public policy.

Keywords: Entrepreneurship; Technology transfer; University intellectual property

1. Introduction

New firms founded to exploit university-assigned intellectual property (TLO start-ups) have become an important economic phenomenon. Roughly 12% of university-assigned inventions are transferred to the private sector through the founding of new organizations (Association of University Technology Managers, 1998). TLO start-ups are also disproportionately successful start-up firms. Of the 2578 technology licensing office (TLO) start-ups that have been founded since 1980, 70% are still in operation (Association of University Technology Managers, 1998). Moreover, research on the TLO start-ups from the Massachusetts Institute of Technology (MIT) indicates that roughly 20% of these companies experience an initial public offering (Shane and Stuart, 2002). In fact, several major corporations had their origins as TLO start-ups, including Genentech in biotechnology, Cirrus Logic in semiconductors, and Lycos in Internet search engines. Thus, across universities, TLO start-ups are both an important vehicle of technology transfer, and an important mechanism for economic activity.

However, the frequency of TLO start-up activity varies significantly across universities. Some universities, like MIT, routinely transfer their technology through the formation of new firms, while other universities, like Columbia University, rarely generate start-ups. Moreover, rates of start-up activity are not a simple function of the magnitude of sponsored research funding or the quantity of inventions created. For example, Stanford University, with sponsored research expenditures of US$ 391 million generated 25 TLO start-ups in 1997; whereas Duke University, with

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sponsored research expenditures of US$ 361 million, generated none. To date we have no systematic explanation for why some universities generate more new companies to exploit their intellectual property than do others.

Explaining cross-school variation in start-up activity is important for at least four reasons. First, university inventions are an important source of knowledge spillovers (Jaffe, 1989), and understanding the different mechanisms by which knowledge from different universities spills over is important to understanding technology creation and economic growth. Second, TLO start-ups tend to locate geographically close to the institutions that spawn them,[2] making them valuable entities for local economic development and agglomeration economies (Zucker et al., 1998). Third, successful TLO start-ups generate significant wealth through initial public offerings, and university inventors and provosts are interested in capturing this wealth. Fourth, university entrepreneurs make different decisions from non-entrepreneurs, leading the creation of TLO start-ups to generate important questions about university norms and policies toward research, teaching, and knowledge disclosure (Cohen et al., 1998; Brooks and Randazzese, 1998).

In this paper, we explore empirically why some universities generate more TLO start-ups than do others. In specific, we examine the number of companies founded to exploit university-assigned intellectual property across 101 US universities over the 1994–1998 period. We investigate four different arguments for cross-institution variation in start-up rates: university policies, local venture capital activity, the commercial orientation of university research, and intellectual eminence. We find that two university policies—making equity investments in lieu of patent and licensing costs, and the inventor share of royalties—and the university's intellectual eminence influence TLO start-up rates. We find no effect of local venture capital activity and only limited support for an effect of the commercial orientation of university research on TLO start-up rates.

This article proceeds as follows: Section 2 presents the four explanations for why some universities generate more TLO start-ups than others do. Section 3 describes the methodology for the study. Section 4 presents the results. Section 5 presents a discussion and conclusions.

[2] The Association of University Technology Managers (1999) reports that 79% of the 364 TLO start-ups in 1998 were founded in the state in which the licensing institution is located.

2. The different explanations

TLO start-ups are created when the licensee of a university-assigned invention creates a new company to exploit it. Both micro and macro-level factors influence the decision to create a new company to exploit a university invention. At the micro-level, research has shown that the attributes of technological inventions themselves (Shane, 2001a), inventors' career experience (Levin and Stephan, 1991; Shane and Khurana, 2000), their psychological make-up (Roberts, 1991), and their research skills (Zucker et al., 1998) influence this decision. At the macro-level, research has shown that technology regimes (Shane, 2001b), the strength of patent protection in a line of business (Shane, 2002), and universities' intellectual property (Goldfarb et al., 2001) and human resource policies (Kenney, 1986) influence this decision. Although both micro- and macro-level factors influence the tendency of people to start new firms to exploit university inventions, we do not discuss micro-level factors in this study. The goal of the paper is to examine the effect macro-level factors that vary across universities over time on the rate at which new firms are created to exploit university inventions rather than to develop an overall behavioral model of the decision to found a firm to exploit university inventions.

Prior research suggests four macro-level explanations for cross-university variation in TLO start-up activity. First, universities located in geographic areas rich in venture capital could be more likely generate TLO start-ups because the abundance of venture capital makes resource acquisition easier for entrepreneurs. Second, universities that conduct industry-funded research could be more likely to generate TLO start-ups because they are more likely than other universities to make commercially-oriented discoveries. Third, universities that are more intellectually eminent could be more likely to generate TLO start-ups because intellectual eminence allows schools to produce new technologies of actual or perceived higher quality. Fourth, universities that adopt certain policies could generate more TLO start-ups because those policies provide greater incentives for entrepreneurial activity. In Sections 2.1–2.4, we develop each of these explanations.

2.1. Venture capital

The first argument for cross-university variation in TLO start-up activity is the availability of venture capital in the area. Venture capitalists play an important role in the innovation process by providing risk capital and operating assistance to new high technology firms (Florida and Kenney, 1988). In fact, venture capital plays a particularly important role in financing university start-ups because it is a major source of funds for new firms in fields in which universities are a major source of new technology, like biotechnology (Zucker et al., 1998).

Because formal venture capital is a major source of equity financing for new technology companies, its availability is important to overcoming capital market barriers to the financing of new technology firms. In addition, venture capitalists serve as "market makers" in a "spot market" for business development resources by connecting new technology companies with potential suppliers, customers, lawyers, manufacturers, and employees (Florida and Kenney, 1988). Finally, venture capitalists provide valuable operating assistance to new technology companies that help those companies to grow and compete.

Venture capital investments tend to be made locally. Moral hazard problems pervade the financing of new technology companies (Sahlman, 1990). Uncertainty and information asymmetry make entrepreneurs privy to information that investors do not have, so it is important for venture capitalists to closely monitor their investments in new companies. Because interpersonal interaction provides a central mechanism for disseminating information, and this interaction is enhanced by physical interaction and inspection (Sorenson and Stuart, 2001), geographical proximity lowers the cost of monitoring new ventures (Gompers and Lerner, 1999; Gupta and Sapienza, 1992; Lerner, 1995; Sorenson and Stuart, 2001).

Second, to link new technology companies with potential suppliers and customers, venture capitalists rely on networks of contacts. These networks are more easily developed and maintained in a localized geographic area (Sorenson and Stuart, 2001). As a result, efforts to provide new ventures with ties to important stakeholders are facilitated by geographically localized investing.

Third, the provision of operational assistance to new technology companies is enhanced by physical proximity to investment targets (Gupta and Sapienza, 1992). Venture capitalists spend between 4 and 5 h per month on the site of the companies in which they invest, and activities with portfolio companies account for half of a venture capitalist's time (Gorman and Sahlman, 1989). Because travel time reduces the number of ventures with which an investor can interact, geographically localized investing increases the amount of operational assistance that a venture capital firm can make. Moreover, the quality of assistance that venture capitalists can offer start-ups decreases with geographical distance (Sorenson and Stuart, 2001).

Several studies have provided empirical support for the geographical localization of venture capital investments (Gompers and Lerner, 1999; Gupta and Sapienza, 1992; Lerner, 1995; Sorenson and Stuart, 2001). In particular, Sorenson and Stuart (2001) find that the probability that a venture capital firm will invest in a start-up decreases with the geographical distance between the headquarters of the venture capital firm and the start-up firm—the rate of investment in companies 10 miles from a venture capitalist's headquarters is double that in companies located 100 miles away. Similarly, Lerner (1995) finds that geographic proximity influences the composition of the boards of directors of venture capital-backed start-ups—venture capital firms headquartered within 5 miles of a start-up's location are twice as likely to be on the company's board of directors as venture capital firms headquartered 500 miles away.

Evolutionary patterns of regional development, combined with resource endowments, have created different distributions of venture capital in different geographical locations (Lerner, 1995). The vast majority of venture capital in the US is located in a small number of locations like Silicon Valley and Route 128 (Florida and Kenney, 1988). If entrepreneurs use venture capital to found new high technology companies to exploit university inventions, and venture capitalists make geographically constrained investments, then the availability of venture capital in a locality should influence the rate of TLO start-up activity. This argument suggests that, ceteris paribus, the greater the availability of venture capital in the university area, the greater the rate of TLO start-up activity.

2.2. Commercially-oriented research

The second argument for cross-university variation in TLO start-up activity is the commercial orientation of university research. Universities differ on the degree to which their researchers focus on industrial problems. Some universities (perhaps because of their state affiliations or their historical involvement with agricultural or industry extension services) focus their research more closely on the needs of industry than do other universities. The commercial orientation of university research is reflected in the source of funding for that research. Commercially-oriented universities receive more of their research budget from industry than do other universities (Rosenberg and Nelson, 1994).

The tendency of a university to conduct industry-funded research and development should increase its TLO start-up rate for three reasons. First, industry tends to fund more commercially-oriented research than the government, and a commercial orientation should increase the likelihood of discovering technologies that have sufficient commercial value for people to found companies.

Second, industry tends to fund less risky research than the government funds (Arrow, 1962). More risky research is more problematic for firm formation because single technology new companies cannot exploit the economies of scope in technology development that allow large firms to diversify these risks (Nelson, 1959).

Third, being more basic, government-funded research tends to suffer from greater information asymmetry problems than does industry-funded research. Because entrepreneurs obtain money through market-mediated transactions,[3] information asymmetry problems result in failures in venture finance markets. Thus, information asymmetry problems make it less likely that entrepreneurs will be able to finance companies to commercialize government-funded research than industry funded research. The above arguments suggest that, ceteris paribus, the greater the amount of commercially-oriented research activity at the university, the greater the rate of TLO start-up activity.[4,5]

2.3. Intellectual eminence

The third argument for cross-university variation in TLO start-up activity is university eminence. Two different variants of the eminence explanation have been suggested in the literature. The first argument is that better quality researchers are more likely to start firms to exploit their inventions than lesser quality researchers; and, on average, higher quality researchers are found in more eminent universities. In some fields, university entrepreneurs found companies to capture the rents to their intellectual capital (Zucker et al., 1998). Because this intellectual capital is tacit, and belongs to a small set of leading researchers, inventors must become entrepreneurs to exploit it. More eminent schools are more likely to employ leading-edge researchers than are less eminent schools. Therefore, the founding of companies to capture rents to intellectual capital will be more common at more eminent schools than at less eminent institutions.

The second argument is that the university's prestige or reputation makes it easier for researchers from more eminent universities to start companies to exploit their inventions than researchers from less eminent universities. Obtaining the resources necessary to establish a technology company requires entrepreneurs to persuade resource providers to give them money under conditions of information asymmetry and

[3] They lack positive cash flow from existing operations.

[4] Readers should note that an alternative argument could be made—the rate of TLO start-ups is inversely proportional to the commercial orientation of university research funding. When a company contributes research funds, it sometimes obtains the right of first refusal to license any discoveries that come from that research. As a result, more industry funding could lead to fewer start-ups because it leads the university to license a greater proportion of its inventions back to the firms that fund the research.

[5] In our regressions to predict the effect of the commercial orientation of university research on the rate of TLO start-up activity, we control for the number of inventions produced in the university-year. This control is important because new firm formation might depend on the attributes of technological inventions themselves (Shane, 2001), rather than on university orientation. As a result, the number of commercially-oriented inventions, rather than the university's commercial orientation might drive the TLO start-up rate. By partialling out the effect of the number of inventions in regression analysis, we can examine the effect of commercial orientation net of the effect of the number of inventions.

uncertainty. Because information problems preclude investors from completely evaluating the technology under question, investors often make their evaluation of entrepreneurs and their ideas on the basis of perceived signals of quality. One signal that investors use is the intellectual eminence of the researchers and the institution spawning the venture (Podolny and Stuart, 1995). Investors believe, rightly or wrongly, that more eminent universities produce technology that is more worthy of funding than less eminent universities, and therefore encourage greater firm formation from more eminent institutions. Both variants of the intellectual eminence argument suggest that, ceteris paribus, the greater the intellectual eminence of the university, the greater the rate of TLO start-up activity.

2.4. University policies

The fourth argument for cross-university variation in TLO start-up activity is that universities differ in their policies toward technology transfer and that those policies shift activities at the margin toward or away from start-up activity. In particular, previous researchers have suggested the importance of four different policies.

First, the distribution of royalty rates between inventors and the university could influence the propensity of entrepreneurs to found firms to exploit university inventions. Universities typically earn profits from their inventions through royalties on the gross sales from licensing that technology. Universities have policies that divide these profits between inventors and the university. This arrangement means that inventors can earn profits from their inventions either from royalties paid by licensees, or from the profits (net of royalties) made from commercializing the technology themselves.[6]

The dual nature of potential inventor compensation from invention creates an inverse relationship between royalties and incentives for inventors to found firms. Assuming constant licensing rates across different licensees for particular types of technology, the inventor's earnings will increase with his or her share of the royalties if the technology is licensed to an existing firm. In contrast, if the inventor starts a company, his or her earnings will not increase with his or her share of the royalties. Therefore, the greater the inventor's share of the royalties, the greater the opportunity cost of starting a firm to exploit the technology, and the lower the incentive to seek profits from an invention by founding a firm. Therefore, ceteris paribus, the size of the inventor's share of royalties should be inversely related to the TLO start-up rate.

Second, the use of incubators could influence the cost of start-up activity. Most university technologies are embryonic and development on them is necessary before they can be sold in the market place (Jensen and Thursby, 2002). Incubators allow entrepreneurs to "ripen" technologies in close proximity to inventors whose inputs are useful for further development. In addition, incubators reduce the cost of development through subsidies and sharing of general administrative costs. Therefore, ceteris paribus, the use of incubators should increase the TLO start-up rate.

Third, the use of internal venture capital funds could make the acquisition of capital easier for TLO start-ups. Venture capitalists are more likely to invest in companies that are referred to them by colleagues or that are founded by people that they know because these ties provide investors with information that mitigates the information asymmetry problems inherent in financing new technology companies (Sorenson and Stuart, 2001).

However, most university personnel are not members of the information networks of venture capitalists. Their focus on research and teaching does not require interaction with venture capitalists, but instead requires interaction with other economic actors. Because university administrators with whom university personnel interact administer university venture capital funds, potential university entrepreneurs are more likely to have direct or indirect connections to the administrators of university venture capital funds than to general venture capitalists. These connections facilitate the flow of information about the potential entrepreneurs and mitigate the information asymmetry problems in venture finance. Therefore, ceteris paribus, the presence of internal venture capital funds should increase the TLO start-up rate.

[6] This argument assumes that the inventor's royalty is not differentially affected by licensing negotiations between the university and the licensing firm, and that that the inventor's income is not differentially affected by the size of after-license consulting contracts, when the licensee is an inventor start-up and when the licensee is an independent entity. Because the current research project cannot examine this assumption, future research should consider its veracity.

Fourth, a university's willingness to take an equity stake in TLO start-ups in exchange for paying patenting, marketing, or other up-front costs could facilitate the formation of start-up companies. Unlike established firms, new firms lack cash flow from existing operations, making them cash constrained. University equity investments made in lieu of paying patent costs or up-front license fees reduce the cash expenditures of new firms, facilitating firm formation (Hsu and Bernstein, 1997). Therefore, ceteris paribus, the willingness of a university to make equity investments in TLO start-ups should increase the TLO start-up rate.

3. Methodology

In this section, we describe the sample and variables included in the analysis, and provide an overview of the analytical methods we employed.

3.1. Sample

Universities regularly retain the right to intellectual property generated by faculty and staff, leading university technology licensing offices to track the life histories of the intellectual property that they create. Because of the interest of universities in tracking their intellectual property, university technology licensing offices are aware of virtually all start-up firms that are created to exploit university intellectual property.

The Association of University Technology Managers (AUTM), a professional association governed by and for TLO officers, annually surveys university technology licensing offices to obtain information pertaining to patenting, licensing, and start-up firm activity, as well as information on funding, staffing, and certain policies. AUTM has collected data pertaining to start-up activity since 1994. Because we use panel data analysis techniques, we gathered data on start-up activity from 1994 to 1998 for the 116 universities for which 2 or more years of TLO start-up data are available from AUTM.

We seek to examine the effect of university policies on the start-up rates. We define a university in our analysis as an entity that operates under a single set of policy rules. Therefore, we aggregated data from multi-campus universities into a single annual observation for the university,[7] except when the different campuses employed distinct policies and procedures and maintained independent TLOs.[8]

Although the dependent variable of interest, TLO start-up activity, was obtained from the AUTM survey, the data for predictor and control variables were obtained from a variety of sources, including venture capital databases, the United States Patent and Trademark Office (USPTO) database, and a survey administered to TLO directors. To obtain information regarding university policies from 1994 to 1998, we surveyed the 116 universities in our sample by both e-mail and telephone. We asked the TLO directors to indicate their policies for each year from 1994 to 1998.

Of the universities surveyed, 101 responded, providing a response rate exceeding 87%. We compared respondents to non-respondents in terms of patenting and start-up activity and found no statistically significant differences at the $P < 0.10$ level. The non-respondents provided a variety of idiosyncratic reasons for not participating (e.g. some do not participate in surveys as a matter of policy, while others had experienced turnover and were unable to provide historical information regarding policies). Therefore, we are confident that non-response to our policy questions does not hinder our analysis.

The sample for our analysis is restricted to the 101 universities that are both in the AUTM database and responded to our survey. Because some universities report start-up data for only some years, our sample consists of 457 university-year observations. However, the sample includes of 89 of the 100 top US universities in R&D volume, and accounts for approximately 85% of all US patents issued to universities, based on statistics maintained by the USPTO. Although the exact number of TLO start-ups is unknown, the sample appears to account for the vast majority of the population of such firms, and selection bias does not hinder our analysis of the data.[9]

[7] The AUTM licensing data is most often reported at the level of the university system. It is not possible to examine campuses of the same system separately.

[8] Although most state medical schools share a single TLO with the state university, we consider three state medical schools separate institutions due to their distinct policies and administration.

[9] It is important to note that the sample represents the population of universities that generate inventions. It does not represent the population of US educational institutions.

To gather data on venture capital activities in different locations, we examined the Venture Economics database, administered by Thomson Financial Services. The Venture Economics database is the leading source of data on venture capital activity in the US (Gompers and Lerner, 1999).

To gather data on intellectual eminence, we utilized the assessment score for overall graduate school quality reported in the Gourman Reports (Gourman, 1994, 1997), a widely used assessment of graduate and professional degree programs. The Gourman Report assessment incorporates the perceived and actual quality of a university's graduate programs in medicine, engineering, business, physical sciences, social sciences, humanities, and other fields into a single measure of graduate school quality.[10] The measure is derived from an assessment of several factors that are believed to influence graduate school quality, including the caliber of faculty, adequacy of facilities, breadth of curriculum, funding levels, and research productivity.

Lastly, we obtained patent data by searching the on-line database of US patents maintained by United States Patent and Trademark Office. For each university-year, we performed a search of the name of the university and/or foundation designated by the university as the assignee for its intellectual property. We then tabulated the total number of patents in each university-year. The results of our search correlated at 0.95 with the self-reported patent data provided by the universities to AUTM.

3.2. Dependent variable

The dependent variable is a count of the number of TLO start-ups from a given university in a given year.

3.3. Predictor variables

3.3.1. Venture capital availability

To measure the effects of venture capital availability on the TLO start-up rate, we examined four measures of local venture capital: the number of local companies receiving funding from venture capitalists in a given year; the amount of venture capital funding received by local firms in a given year; the number of local venture capital funds in a given year; and the amount of funding provided by local venture capital funds in a given year.[11,12,13] We defined local venture capital as the amount of activity occurring in all telephone area code zones within 60 miles of the each university.[14] Area codes were used to delineate geographic areas in order to avoid errors of inclusion or omission that would be likely to occur by defining regions by state.

3.3.2. Commercially-oriented research

To measure if the commercial orientation of university research increased the TLO start-up rate, we examined the proportion of each university's sponsored research budget in a given year that was industry funded.[15] Because overall magnitude may be more important than percentage allocation, in an alternative specification, we measured commercial orientation as the dollar value of industry funding, while controlling for government funding. We gathered these data from the AUTM licensing survey.

3.3.3. Intellectual eminence

To measure if university eminence increased the TLO start-up rate, we examined the overall academic rating score of graduate schools published in the Gourman Reports (Gourman, 1994, 1997). Because this survey is produced every 3 years, we update the scores in 1994 and 1997. Three medical schools in the

10 We also examined regressions that substituted the engineering school ranking for the overall ranking. The results are substantively the same as those with the overall rankings. We do not report the analysis with the engineering school rankings because the sample size is reduced by 21 universities that do not offer graduate degrees in engineering.

11 We do not lag the independent variables because we expect that the current year independent variables, rather than past year independent variables, influence the start-up decision.

12 In our regression analysis, we use the number of local companies receiving venture capital funding in a given year as our primary measure and treat the other measures as tests of robustness in other regressions.

13 Because the venture capital measures are non-normally distributed, we also examined natural log and square root transformations. The results for the transformed variables are qualitatively the same as those for the untransformed variables. We report the untransformed variables for ease of interpretation.

14 The area code was available for approximately 85% of the data in the database.

15 Prior research shows that this proportion captures the university tendency to conduct applied research (Henderson et al., 1998).

sample do not offer graduate degrees in fields outside of health sciences, and therefore did not receive overall graduate school scores in the Gourman Report. For these universities, we used the scores for their medical schools in our regression analysis. In unreported regressions, we examined the data excluding the three problematic institutions. We find that their inclusion or exclusion does not qualitatively alter the results.

3.3.4. University licensing policies: the inventor share of royalties

To measure if royalty policies influenced the TLO start-up rate, we examined the inventor's share of royalties from technology licensing. The inventors of technologies licensed by universities receive royalties based on a rate that is virtually always explicitly stated in published university policies. The percent of royalties distributed to inventors may be constant, as is the case in the majority of universities included in our sample, or may be established on a sliding scale that typically decreases according to the amount of royalties received by the university. We contend the distribution rate affects start-up activity by altering the perceived opportunity cost of an inventor. Because the inventor's share of royalty rates sometimes forms a range that is affected by the outcome of the license (i.e. declining or increasing percentages as sales increase), inventors cannot know ex ante the exact share of royalties that they will receive. Therefore, in our primary analysis, we use the minimum percent of total royalties distributed to inventors as an indicator of the perceived opportunity cost. In alternative regressions, we measured the distribution of royalties by the amount of royalties an inventor would receive on a patent that yields US$ 1 million in royalties for the university. While this amount clearly exceeds the average amount of royalties received for university patents, inventors are most likely to start a firm to exploit their technology when they believe their invention has better-than-average prospects.

3.3.5. University licensing policies: incubators

To measure if the presence of incubators influenced the TLO start-up rate, we examined whether or not TLO start-ups had access to technology incubators. University officials often argue that they can enhance the start-up rate out of their TLOs by using incubator facilities to foster new companies. In some instances, university incubators may be independently operated, but work jointly with the university. In other cases, the incubators may be units of the university.[16] In our survey, we asked the TLO directors whether or not the university provided access to either type of incubator for TLO start-up firms during each year from 1994 to 1998. We included a dummy variable of one for the university-year in our regression analysis if the response was affirmative.

3.3.6. University licensing policies: equity policies and practices

To measure if equity policies influenced the TLO start-up rate, we examined whether or not the TLO could make an equity investment in TLO start-ups. Anecdotal evidence suggests that a university policy of making an equity investment in lieu of requiring reimbursement of patenting and licensing expenses will enhance the university start-up rate by reducing capital constraints on firm formation. We measured this practice through the use of a dummy variable of one in the university-year if the information provided by each university to AUTM indicated that the university took an equity stake in at least one licensee in any prior year.

We also tested an alternative measure of equity policies derived from the surveys we sent to TLO directors. We asked the TLO directors whether or not their university was permitted to take an equity stake in licensees of university intellectual property for each of the years covered in the study. This indicator variable took a value of one if the university's policies did not explicitly prohibit the university from taking an equity stake in a licensee in a given year.

3.3.7. University licensing policies: venture capital investment by universities

To measure if university venture capital funds influenced the TLO start-up rate, we asked TLO directors to indicate whether or not their universities were permitted to make venture capital investments in licensees of university technologies. We include a dummy variable

[16] As an indicator variable, this measure does not account for variation in size, funding, and quality of assistance among incubators.

of one if the university is permitted to make venture capital investments in licensees in a given year.[17]

3.4. Control variables

3.4.1. Number of inventions

Because we expect that the number of TLO start-ups would be related to the number of inventions produced by the university, we control for the production of technology in three different ways. First, we examine the number of patents issued to the university in the year under investigation. Second, we examine the number of invention disclosures in the university-year. Third, we examine the number of licenses and option agreements signed in the university-year.[18] We examine each of these measures of inventive output (in different regressions) because each measure has advantages and disadvantages. Invention disclosures capture the overall inventive activity at a university, whether or not those inventions are of interest to firms. Invention disclosures are also less biased by the patentability of inventions in different types of technology (e.g. software should generate fewer patents per invention than will drugs), than patents. However, universities have different rules about invention disclosures, making them more subject to institutional variation in their measurement than patents, which must meet the same federal requirements. In addition, some universities pre-screen potential inventions and encourage inventors to disclose only if they believe that the inventions are patentable.[19]

Unlike invention disclosures and patents, licenses and option agreements capture the production of technology that is of interest to the private sector. By controlling for licensing agreements, rather than invention disclosures or patents, we can measure the frequency of start-up activity, ruling out the possibility that we are simply capturing the commercial value of different schools' inventive output. As a result, using this control for inventive output, we capture the idea that there are many inventions that are not of interest to the private sector, and that there are routes to commercialization other than start-ups.

The invention disclosure and licensing data were derived from the AUTM surveys, while patent data were obtained from the United States Patent and Trademark Office database.

3.4.2. Number of technology licensing office staff

The assistance in technology transfer that entrepreneurs require may exceed that required by established companies. In addition, licensing contracts with start-ups often involve exclusive licensing (Jensen and Thursby, 2002), and the negotiations for such contracts may be more time intensive. Therefore, we control for the number of technology licensing office staff, measured in full-time equivalencies (FTEs).

3.4.3. Sponsored research expenditures

Because the intellectual property exploited by TLO start-ups is created through investment in research, the amount of research inputs is likely related to start-up rates. Therefore, we control for the amount of sponsored research expenditures in the university-year. We control for total sponsored research funding, except in a model that includes industry funding (rather than industry funding as a percent of total funding) as a predictor variable. In the latter case, we control for the total amount of government funding.[20] We gather these data from information reported by the universities to AUTM.

3.4.4. Year dummy variables

Patenting and start-up activity is significantly higher in 1997 and 1998 than in other years. To account for annual variations in patenting and start-up activity, we

[17] The venture capital investment variable reflects the explicit policies of universities. It is also correlated with the previous variable, equity investment, because a university must first be able to take an equity stake in a licensee (i.e. a passive form of investment) in order to make a direct venture capital investment in the licensee.

[18] We also examined the number of patent applications in place of the number of patents issued. The results are substantively the same with patent applications as with patents issued.

[19] We also explored whether lagging patent applications and invention disclosures changes the effects of these variables. The results are substantively the same when we lag each of these variables by 2 years. Because we do not know the actual lag between invention disclosure or patent application and start-up, the length of the time lag we selected was arbitrary. Therefore, we report the regression analyses with the unlagged variables.

[20] Because this variable is non-normally distributed, we also examined the square root of this variable. The results are qualitatively the same with the transformed and non-transformed variables. For ease of interpretation, we report the results with the non-transformed variables.

include indicator variables for all but the first year of the sample period.

3.5. Estimation and model specification

We analyzed the 5-year panel compiled for this study utilizing negative binomial models in generalized estimating equations (GEE), which are an extension of generalized linear models applied to longitudinal data (Liang and Zeger, 1986). Our choice of analytic technique depended on five factors: (1) our dependent variable took the form of count data; (2) the standard errors are likely to be auto correlated over time; (3) the covariance structure itself was not of central interest to us; (4) a significant portion of our sample involved schools that generate no start-ups during our observation period; and (5) unobserved school-level heterogeneity likely influences start-up activity.

We employed a negative binomial estimator because our data takes the form of count data with large numbers of zeros. Consequently, ordinary least squares regression is inappropriate. When we examined the distribution of the dependent variable as a Poisson, a goodness-of-fit test rejected the Poisson distribution assumption because of over-dispersion, suggesting that negative binomial models are more appropriate than Poisson models to analyze the data. Therefore, we ran negative binomial models to predict the number of start-ups for each school in each year.

The use of a generalized linear model for time series data corrects for the problem of auto correlation that results from unobserved factors influencing patterns in particular schools over time (Greene, 1990). In particular, the generalized linear model we used corrects for autocorrelation of residuals (Liang and Zeger, 1986).

GEE is also the most appropriate technique for the analysis of non-Gaussian longitudinal data for which the dependence of the outcome on the covariates requires estimation but the covariance structure across time is not of central interest (Liang and Zeger, 1986). Because we had multiple observations for each university and we wanted to account for the covariance relationships over time, we specified the correlation between the error terms to be exchangeable—correlated similarly across time for each school to account for expected correlations between the errors for each school over time. Alternatively, we could have also justified assuming either an auto-regressive (AR) or an unstructured correlation structure. Therefore, we also estimated AR1 and unstructured models in order to assess the robustness of our results. In both cases, assuming an alternative correlation structure had no meaningful impact on the significance or magnitude of the results.

Of the 101 schools in the sample, 17 had no start-up activity in any year. Typical fixed effects models for estimating panel data cannot estimate effects for samples that include respondents for which there is no variation in the dependent variable over time. However, we expect that universities for which we observe no TLO start-up activity over the observation period are systematically different from those in which there was some start-up activity. Therefore, dropping those observations would likely bias the estimates in the regression analysis. Estimating our regressions using GEE allowed for the inclusion of universities for which no start-up activity was observed during the sample period.

Initially, we also employed random-effects estimators clustered on schools to deal with the potential for unobserved heterogeneity in explaining the start-up rates across schools. However, a Hausman test indicated the assumptions upon which the random-effects model is dependent were untenable. For purposes of comparison, we also report a model without robust clustering on university as well as a random-effects negative binomial model. As is shown below, the results of these models are not markedly different from the core GEE model, lending confidence in the robustness of our results to the choice of analytic technique.[21]

4. Results

Table 1 presents summary statistics for all variables included in the sample. Table 2 presents the results of the regression analysis. In Table 2, model 1 provides the main model. Models 2–9 provide a series of robustness checks using alternative measures for

[21] The random-effects model allows us to rule out the possibility that the results we present are artifacts of unobserved heterogeneity in such things as the relative emphases of different schools on different scientific fields and the presence or absence of engineering and medical programs.

Table 1
Descriptive statistics

Variable	Observations	Mean	S.D.	S.D. between schools	S.D. within schools	Minimum	Maximum
Number of TLO start-ups in year	457	2.083	3.116	2.523	1.733	0.000	25.000
Number of VC-funded local firms	457	72.591	128.461	115.944	49.631	0.000	1194.000
Number of local VC funds	457	44.842	80.856	76.248	23.218	0.000	421.000
US$ (in millions) provided to local firms	457	591.670	1020.137	841.047	552.975	0.000	9202.840
US$ (in millions) provided by local funds	457	795.501	1803.332	1597.979	771.139	0.000	9604.690
Industry/total sponsored research funds	457	0.104	0.082	0.074	0.036	0.005	0.560
Industry sponsored funding (US$ in millions)	457	15.952	18.666	17.287	5.863	0.303	162.432
Gourman graduate school score	457	3.837	0.762	0.772	0.001	2.080	4.940
Minimum inventor share of royalties (%)	457	35.463	10.272	10.077	2.127	10.000	50.000
Inventor share of royalties from a patent yielding US$ 1 million (%)	457	36.890	9.611	9.567	1.563	15.000	65.000
Has university-affiliated incubator (1 = yes)	457	0.344	0.475	0.460	0.111	0.000	1.000
Has previously taken an equity stake (1 = yes)	457	0.740	0.439	0.420	0.185	0.000	1.000
Permitted to take equity (1 = yes)	457	0.796	0.403	0.386	0.135	0.000	1.000
Permitted to make VC investments (1 = yes)	457	0.435	0.496	0.493	0.066	0.000	1.000
Patents	457	21.260	34.757	31.876	11.141	0.000	415.000
Invention disclosures	457	79.440	89.614	85.227	19.871	0.000	742.000
TLO staff members (FTEs)	457	6.765	11.339	10.826	1.461	0.000	103.500
Total sponsored research funding (US$ in millions)	457	184.182	207.478	199.067	31.486	7.966	1709.929
Government-sponsored funding (US$ in millions)	457	119.217	138.101	128.519	39.156	2.975	933.210
Licenses to all firms in year	452	23.861	29.818	27.617	9.864	0.000	191.000
Licenses to established firms in year	452	21.774	27.948	25.767	9.648	0.000	186.000

Table 2
Model estimation

	Model						
	1	2	3	4	5	6	7
Venture capital availability							
Number of VC-funded local firms (in thousands)	1.142 (1.018)	1.064 (0.986)	0.887 (0.655)	1.034 (0.470)	1.110 (0.896)		
Number of local VC funds (in thousands)						0.967 (0.957)	
US$ (in billions) provided to local firms							0.949 (0.090)
US$ (in billions) provided by local funds							
Commercially-oriented research							
Industry/total sponsored research funds	2.035 (2.198)	2.044 (2.260)	1.476 (1.528)	2.625 (2.849)		1.991 (2.169)	1.850 (1.959)
Industry sponsored funding (US$ in millions)					1.013** (0.006)		
Intellectual eminence							
Gourman graduate school score	1.676*** (0.262)	1.812*** (0.271)	1.490** (0.214)	1.533** (0.225)	1.633*** (0.214)	1.679*** (0.258)	1.684*** (0.262)
University licensing policies							
Minimum inventor share of royalties	0.980** (0.006)	0.974*** (0.006)	0.985** (0.006)	0.983** (0.006)	0.980*** (0.006)	0.980** (0.006)	0.981** (0.006)
Inventor share of royalties from a patent yielding US$ 1 million							
Has university-affiliated incubator	1.129 (0.180)	1.294 (0.214)	1.130 (0.165)	1.147 (0.169)	1.111 (0.184)	1.123 (0.181)	1.112 (0.177)
Has previously taken an equity stake	1.886** (0.389)		1.902** (0.397)	1.836** (0.391)	1.837** (0.378)	1.882** (0.388)	1.869** (0.383)
Permitted to take equity		1.687* (0.372)					
Permitted to make VC investments	0.881 (0.144)	0.825 (0.147)	0.966 (0.148)	0.832 (0.128)	0.933 (0.156)	0.890 (0.151)	0.912 (0.150)
Control variables							
Patents	1.004 (0.004)	1.003 (0.004)			1.002 (0.003)	1.004 (0.003)	1.005 (0.003)
Invention disclosures			1.005*** (0.001)				
License agreements				1.012*** (0.002)			
TLO staff members (FTEs)	0.990 (0.010)	0.995 (0.010)	0.982** (0.009)	0.982† (0.010)	0.995 (0.007)	0.990 (0.010)	0.991 (0.010)
Total sponsored research funding (US$ in millions)	1.002† (0.001)	1.002 (0.001)	1.001 (0.001)	1.002* (0.001)		1.002† (0.001)	1.002† (0.001)
Government-sponsored funding (US$ in millions)					1.001 (0.001)		
Fiscal year 1995	0.976 (0.126)	1.045 (0.142)	0.949 (0.120)	1.000 (0.130)	1.008 (0.132)	0.977 (0.127)	0.984 (0.128)
Fiscal year 1996	0.987 (0.153)	1.077 (0.169)	0.948 (0.149)	0.977 (0.159)	1.030 (0.156)	0.994 (0.156)	1.020 (0.155)
Fiscal year 1997	1.236 (0.180)	1.355* (0.200)	1.133 (0.163)	1.193 (0.179)	1.258 (0.185)	1.247 (0.179)	1.289† (0.183)
Fiscal year 1998	1.256 (0.189)	1.397* (0.214)	1.190 (0.184)	1.227 (0.178)	1.289† (0.189)	1.267 (0.189)	1.318† (0.200)
Wald X^2 (degrees of freedom)	167.96*** (14)	186.78*** (14)	211.88*** (14)	314.29*** (14)	200.98*** (14)	163.37*** (14)	170.93*** (14)

	8	9	10	11	12	13
Venture capital availability						
Number of VC-funded local firms (in thousands)		1.128 (0.985)	1.142 (0.913)	0.873 (0.490)	1.217 (1.189)	1.147 (0.994)
Number of local VC funds (in thousands)						
US$ (in billions) provided to local firms						
US$ (in billions) provided by local funds	0.990 (0.035)					
Commercially-oriented research						
Industry/total sponsored research funds	1.958 (2.109)	2.276 (2.427)	2.035 (2.272)	2.937 (2.811)	2.745 (2.957)	1.934 (2.021)
Industry sponsored funding (US$ in millions)						
Intellectual eminence						
Gourman graduate school score	1.685*** (0.261)	1.670*** (0.251)	1.676** (0.275)	1.792*** (0.248)	1.818*** (0.300)	1.636*** (0.249)
University licensing policies						
Minimum inventor share of royalties	0.980** (0.006)		0.980* (0.009)	0.985* (0.008)	0.980** (0.007)	0.979** (0.006)
Inventor share of royalties from a patent yielding US$ 1 million		0.974*** (0.007)				
Has university-affiliated incubator	1.124 (0.181)	1.136 (0.181)	1.129 (0.237)	1.146 (0.197)	1.264 (0.218)	1.168 (0.183)
Has previously taken an equity stake	1.876** (0.385)	1.887** (0.392)	1.886** (0.410)	2.087*** (0.407)	1.828* (0.458)	1.924** (0.398)
Permitted to take equity						
Permitted to make VC investments	0.896 (0.154)	0.871 (0.140)	0.881 (0.174)	0.862 (0.142)	0.840 (0.148)	0.895 (0.147)
Control variables						
Patents	1.004 (0.003)	1.003 (0.003)	1.004 (0.004)	1.001 (0.002)	1.003 (0.004)	1.004 (0.003)
Invention disclosures						
License agreements						
TLO staff members (FTEs)	0.991 (0.010)	0.991 (0.010)	0.990 (0.014)	0.998 (0.010)	0.987 (0.010)	0.986 (0.010)
Total sponsored research funding (US$ in millions)	1.002† (0.001)	1.002† (0.001)	1.002* (0.001)	1.001* (0.001)	1.002* (0.001)	1.002* (0.001)
Government-sponsored funding (US$ in millions)						
Fiscal year 1995	0.978 (0.126)	0.970 (0.126)	0.976 (0.156)	1.037 (0.138)	0.959 (0.133)	0.971 (0.126)
Fiscal year 1996	1.001 (0.157)	0.990 (0.155)	0.987 (0.162)	1.008 (0.138)	0.946 (0.149)	0.981 (0.152)
Fiscal year 1997	1.256 (0.178)	1.226 (0.182)	1.236 (0.203)	1.336* (0.177)	1.284 (0.201)	1.232 (0.179)
Fiscal year 1998	1.279† (0.187)	1.257 (0.191)	1.256 (0.214)	1.325* (0.183)	1.256 (0.203)	1.249 (0.190)
Wald X^2 (degrees of freedom)	161.55*** (14)	173.47*** (14)	95.97*** (14)	141.38*** (14)	154.99*** (14)	171.92*** (14)

Dependent variable: start-ups (models 1–13). Number of observations/groups: 457/101 (models 1–3, 5–11 and 13); 452/100 (model 4); 405/86 (model 12). Model specification: GEE, semi-robust (models 1–9); GEE (model 10); NBREG, semi-robust (model 11); GEE, semi-robust, AR1 (model 12); GEE, semi-robust, unstructured (model 13). The coefficients are exponentiated betas. Standard errors are in parentheses.

† $P \leq 0.10$.

* $P \leq 0.05$.

** $P \leq 0.01$.

*** $P \leq 0.001$.

predictor and control variables. Models 10–13 provide robustness checks by examining alternative estimation techniques. Overall, the results provide substantial evidence that universities' intellectual eminence and licensing policies have a significant impact on TLO start-up activity, while providing little evidence that venture capital availability and the commercial orientation of research influence TLO start-up activity.

The university's intellectual eminence significantly predicts TLO start-up activity. The estimated coefficient for this variable,[22] shown in model 1, implies, ceteris paribus, that an improvement in graduate school quality by one point is associated with a start-up rate of 1.68 times the base rate. Put differently, an increase in intellectual eminence by one standard deviation is associated with approximately one additional start-up firm per year. Thus, more eminent universities appear not only to generate a greater amount of patentable intellectual property, but also—since licenses, patents, and invention disclosures are controlled for in the models we have estimated—create more start-ups to exploit that intellectual property.

Although the precise mechanism through which this effect operates is not entirely clear, we have offered two explanations. First, researchers from more prestigious universities are better researchers and thus are more likely to create firms to capture the rents to their rare and valuable intellectual property (Zucker et al., 1998). Second, since investors use signals, such as institutional reputation or prestige, to help assess the commercial potential of university technologies, inventors from more prestigious universities may be better able to obtain the necessary capital to start their own firms.

Our findings also indicate that two sets of university licensing policies—policies regarding the distribution of royalties to inventors and whether or not the university is permitted to take an equity stake in licensees—appear to influence start-up activity. As in the case of intellectual eminence, these results are robust to different estimation techniques, and are also robust to different operationalizations of the predictor variables. Ceteris paribus, the minimum percentage of royalties distributed to inventors is inversely related to start-up activity such that an increase in the inventor's share of royalties by 10% implies 0.40 *fewer* start-up firms per year, a decrease of 20% from the mean. When royalties are measured by the amount distributed to inventors on a patent yielding US$ 1 million in total royalties, rather than the minimum distribution rate, the effect size is even greater. By increasing the opportunity cost of starting up a new venture, a high inventor share of royalties provides a disincentive to potential inventor-entrepreneurs.

The other licensing policy that appears to influence start-up activity is equity policy. Ceteris paribus, universities that have previously demonstrated a willingness to take an equity stake in licensees in exchange for paying up-front patenting and licensing expenses have a start-up rate that is 1.89 times that of universities that have not demonstrated a willingness to take equity. When equity practices are assessed by the universities' explicit policies rather than their actual practice, the effect size is slightly diminished. Universities that are permitted to take an equity stake in licensees report a start-up rate 1.69 times that of universities that are not permitted to make equity arrangements. Universities that retain the ability to accept an equity stake in licensees instead of direct reimbursement for patenting and licensing costs appear to foster greater start-up activity by providing greater liquidity to entrepreneurs.

The two additional policy variables that we tested—the presence of a university-affiliated incubator and whether or not the university is permitted to actively make venture capital investments in licensees—do not appear to have an impact on start-up activity. The coefficient on the incubator indicator variable is positive as expected, but is not significant. The coefficient on the venture capital investment indicator variable is actually negative, but is also not significant. Therefore, we find no evidence that these practices influence TLO start-up activity.

Our findings provide little support for the contention that universities that conduct more commercially-oriented research will experience greater TLO start-up activity. When commercial orientation is measured by the percentage of total sponsored research funding that is derived from industry sources, the estimated coefficient is positive but is not significant. However, in an alternative specification in which commercial orientation is measured by the dollar amount of industry funding (model 5), the coefficient for industry

[22] In all of the models, we report the exponentiated coefficients for ease of interpretation.

Table 3
Model estimation: elite and non-elite sub-samples

	Model							
	1-Elite	2-Elite	3-Elite	4-Elite	1-Non-Elite	2-Non-Elite	3-Non-Elite	4-Non-Elite
Venture capital availability								
Number of VC-funded local firms (in thousands)	2.478 (2.072)	2.354 (2.042)	1.632 (1.425)	2.113 (1.813)	0.943 (1.222)	1.502 (1.855)	0.742 (0.942)	0.991 (1.267)
Number of local VC funds (in thousands)								
US$ (in billions) provided to local firms								
US$ (in billions) provided by local funds								
Commercially-oriented research								
Industry/total sponsored research funds	37.425** (53.790)	33.845** (46.978)	18.586** (21.304)		0.630 (0.874)	0.799 (1.220)	0.546 (0.804)	
Industry sponsored funding (US$ in millions)				1.014* (0.007)				1.008 (0.012)
Intellectual eminence								
Gourman graduate school score	1.826* (0.512)	1.861* (0.523)	1.526* (0.318)	1.615† (0.466)	1.347 (0.637)	1.553 (0.624)	1.493 (0.712)	1.626 (0.783)
University licensing policies								
Minimum inventor share of royalties	0.978*** (0.005)	0.974*** (0.006)	0.985** (0.005)	0.976*** (0.005)	0.987 (0.018)	0.974 (0.016)	0.990 (0.016)	0.986 (0.016)
Inventor share of royalties from a patent yielding US$ 1 million								
Has university-affiliated incubator	1.264 (0.252)	1.322 (0.272)	1.292† (0.195)	1.239 (0.261)	1.091 (0.364)	1.428 (0.407)	1.069 (0.352)	0.975 (0.303)
Has previously taken an equity stake	1.549* (0.346)		1.645* (0.401)	1.573* (0.356)	2.497** (0.756)		2.528** (0.757)	2.316** (0.737)
Permitted to take equity		1.492* (0.269)				2.587** (0.800)		
Permitted to make VC investments	0.737† (0.134)	0.701* (0.127)	0.898 (0.126)	0.774 (0.138)	1.127 (0.350)	0.929 (0.295)	1.191 (0.379)	1.150 (0.337)
Control variables								
Patents	1.002 (0.003)	1.002 (0.003)		1.000 (0.003)	1.018 (0.012)	1.023† (0.012)		1.028** (0.011)
Invention disclosures			1.006*** (0.001)				1.003 (0.007)	
TLO staff members (FTEs)	0.991 (0.007)	0.993 (0.006)	0.981** (0.007)	0.991 (0.006)	1.019 (0.040)	1.037 (0.040)	1.020 (0.045)	1.026 (0.037)
Total sponsored research funding (US$ in millions)	1.002* (0.001)	1.001* (0.001)	1.001 (0.000)		1.005* (0.002)	1.005* (0.002)	1.005† (0.003)	
Government-sponsored funding (US$ in millions)				1.001 (0.001)				1.007† (0.004)
Fiscal year 1995	0.922 (0.145)	0.980 (0.160)	0.888 (0.140)	0.938 (0.149)	1.132 (0.268)	1.188 (0.308)	1.112 (0.256)	1.158 (0.273)
Fiscal year 1996	0.963 (0.196)	1.016 (0.214)	0.898 (0.181)	0.982 (0.195)	1.106 (0.293)	1.126 (0.326)	1.115 (0.308)	1.131 (0.310)
Fiscal year 1997	1.202 (0.241)	1.277 (0.252)	1.041 (0.203)	1.182 (0.236)	1.215 (0.314)	1.350 (0.360)	1.256 (0.317)	1.223 (0.324)
Fiscal year 1998	1.116 (0.210)	1.171 (0.219)	1.010 (0.208)	1.147 (0.217)	1.261 (0.381)	1.498 (0.435)	1.351 (0.379)	1.277 (0.391)
Wald X^2 (degrees of freedom)	112.64*** (14)	107.60*** (14)	173.39*** (14)	137.69*** (14)	126.47*** (14)	99.64*** (14)	91.59*** (14)	119.22*** (14)

Dependent variable: start-ups (all models). Number of observations/groups: 236/51 (models 1-Elite, 2-Elite, 3-Elite and 4-Elite); 221/50 (models 1-Non-Elite, 2-Non-Elite, 3-Non-Elite and 4-Non-Elite). Model specification: GEE, semi-robust (all models). The coefficients are exponentiated betas. Standard errors are in parentheses.

† $P \leq 0.10$.

* $P \leq 0.05$.

** $P \leq 0.01$.

*** $P \leq 0.001$.

funding is positive and significant. A US$ 10 million increase in industry sponsored research funding is associated with an increase in start-up activity of 0.13 firms (6.7%) per year, ceteris paribus.

Finally, our results provide no evidence that TLO start-up activity is influenced by the local availability of venture capital funding. We operationalized local venture capital availability in four different ways (i.e. models 1 and 6–8), and the coefficients are not significant in any of the models we estimated.

As a robustness check, we examined the predictive validity of our main model on sub-samples of more eminent and less eminent schools by dividing our sample in half at the median on the eminence score. We show these results in Table 3. For the more eminent schools, we find that our results are even stronger than for the entire sample. Intellectual eminence and equity policies have a positive effect and the inventor's share of royalties has a negative effect on the start-up rate. Moreover, the magnitude of the coefficients is greater than that for the overall sample. For this sub-sample, we still find no effect for local venture capital. However, for more eminent universities, the industry share of sponsored research has a positive effect on start-up rates.

In contrast, our model holds less well for less eminent universities. For this sub-sample, we find that only the policy of taking equity appears to influence start-up rates. Overall, the examination of the sub-samples supports our overall findings, but suggests that start-up rates at less eminent universities are driven by more idiosyncratic factors than start-up rates at more eminent institutions.

5. Discussion

In this study, we compared four different explanations for cross-institutional variation in new firm formation rates from TLO offices over the 1994–1998 period—the concentration of venture capital in the area; the reliance of university research and development on industry funding; intellectual eminence; and university policies. The results show that the intellectual eminence of the university, and the policies of making equity investments in TLO start-ups and maintaining a low inventor share of royalties increase new firm formation activity.

We believe that one of the major strengths of this study is that the sampled universities jointly account for the vast majority of university patenting activity in the US. By extension, they most likely account for the vast majority of TLO start-ups. Another major strength of the study concerns the mitigation of selection bias. By examining technology licensing office start-ups, we examine a documented source of new companies, thereby minimizing the problems of selection bias in accounting for start-up activity to exploit other types of new technology developed in universities.

However, our research design limits our sample to the most active research universities, and is therefore not a random sample of all higher education institutions. Moreover, our approach limits our analysis to new firm formation to exploit university-assigned technology. Therefore, our ability to generalize to colleges and universities that are not research-oriented, or to generalize to start-up activity that is not designed to exploit university-assigned intellectual property, is limited. For instance, we have found that a commercial orientation, the availability of venture capital funds, and TLO policies and practices such as the presence of an incubator do not predict TLO start-up activity among the sampled universities. We cannot rule out the possibility that these practices may facilitate start-up activity among colleges and universities that are not research-oriented or influence other types of university start-up activity.

Nevertheless, our findings have four important implications for research on and policy towards university technology transfer and start-up activity. First, we find no evidence to support the argument that capital market constraints limit TLO start-up activity in particular locations. Although other forms of private equity (e.g. angel capital) might influence start-up activity in ways that we cannot observe, we find that the amount of formal venture capital available in a particular location has no significant effect on start-up activity out of TLOs once university technology production is measured. This result is consistent with the work of Zucker et al. (1998) who found that venture capital availability did not significantly influence start-up activity in biotechnology once the distribution of intellectual capital across time and space was considered. Our findings, like Zucker et al. (1998), suggest that capital markets distribute venture capital efficiently over geographic space; and the availability of local venture capital is not a constraint on TLO start-up activity.

This result also suggests that venture capitalists may be late stage investors in university technology. Other sources of funds, such as angels, government agencies, and universities themselves (through equity investment in their own start-ups), may be more important in the early stages, and thus may be catalysts for new firm formation and economic development. Our findings direct further research efforts towards investigating the relative importance of both different funding entities and funding constraints on firm formation as a mode of exploitation of university technology.

Second, although the effect of industry funding on start-up activity may be lagged in ways we cannot estimate, or influence start-up activity in a way that we cannot observe, we fail to find adequate support for the argument that industry funding of university research makes TLO start-up activity more likely. In fact, our results are consistent with anecdotal information on TLO start-ups that suggest that many of these companies seek to exploit basic scientific discoveries (Association of University Technology Managers, 1996).

One reason why the commercial orientation of a university does not predict its start-up rate could be countervailing effects of commercial orientation. Although a commercial research orientation might generate a pool of university inventions that are more appropriate for new firm formation than is generated from a governmental research orientation, the funding structure necessary to generate university inventions might mitigate the benefits of this better pool of inventions. Because private firms might be very likely to license commercially valuable inventions that are generated from research that they fund, any increase in the pool of commercially valuable inventions that a commercial orientation creates may be siphoned off by greater invention licensing by the private sector providers of research funds. As a result, there is no net effect on the TLO start-up rate of the university's commercial orientation.

Nevertheless, the observation that TLO start-ups are as likely to occur when government funds university research as when the private sector does so raises several interesting and important policy questions that future researchers may wish to explore. For example, how should universities manage TLO start-up activities given that taxpayer funds have been used to fund that research? And what role will universities play in technological development if basic research is transferred to the private sector through proprietary start-up ventures?

Third, we find evidence that several university technology transfer policies enhance TLO start-up activity. In particular, a low inventors' share of royalties and a willingness to make equity investments in TLO start-up companies increase start-up activity. These findings suggest that universities can make policy decisions to generate greater numbers of TLO start-ups. These policy tools are important because start-ups and established firm licensees differ in several important ways, including their tendency to contribute to local economic development, their tendency to generate significant income for universities, and their decisions toward knowledge disclosure and research norms. Understanding the implications of these policy tools is also important because they may generate conflicting incentives. In particular, many universities distribute a high percentage of royalties to inventors in order to encourage the reporting and exploitation of inventions; however, our results suggest that high distribution rates also serve as a disincentive to the creation of start-up firms.

The results also show, however, that many policies advocated as mechanisms to increase TLO start-up activity appear to have little effect. In particular, the effects of university-affiliated incubators and university venture capital funds are insignificant. One reason why the presence of incubators has an insignificant effect on start-up rates may be that potential entrepreneurs do not consider the use of incubators when making the start-up decision. Consequently, the existence of incubators merely shifts the location of start-ups (to incubators from outside) rather than increasing the amount of them. Although we can conclude that having access to an incubator does not influence the rate of TLO start-up activity; our analysis cannot determine if university-affiliated incubators influence the success of TLO start-ups.

One reason why university venture capital funds have an insignificant effect on start-up rates may be that university entrepreneurs develop adequate ties to external venture capitalists to provide the investors with information about them through technical due diligence or other activity. As a result, TLO entrepreneurs can obtain adequate amounts of external venture capital. Therefore, university venture capital merely substitutes for, rather than adds to, external venture capital in its effect on start-up activity. Although we cannot be sure why these policies have no effect on start-up rates, we believe that university officials, researchers, and policy makers will find the evidence in support of some policies and not in support of others useful in developing explanations for and procedures toward the management of university technology transfer and TLO start-up activity.

Fourth, our results show more eminent universities have greater TLO start-up activity than other universities. This result is consistent with the argument that leading researchers found companies to earn rents on their intellectual capital (Zucker et al., 1998). It is also consistent with the argument that gathering the necessary resources to found a company to exploit uncertain new technology is easier when the university's status enhances the entrepreneur's credibility.

The tendency for TLO start-ups to come disproportionately from eminent universities also generates important implications for researchers seeking to explain the creation of new technology companies, as well as policy makers interested in influencing the mode of technology transfer out of universities. In particular, the results suggest that researchers and policy makers consider the impact on university technology transfer and industry evolution of the tendency for new technology companies to emerge from eminent universities.

In short, significant differences exist across universities in their generation of new firms to exploit university inventions. Both university policies and intellectual eminence influence this variation, generating important implications for research on and policy towards university technology transfer. Although this paper provides a survey of the effects of university equity investment and royalty policies, intellectual eminence, and funding sources on university TLO start-up activity across a broad spectrum of universities, future research should examine each of these factors in a more fine-grained manner. Hopefully, other scholars will view this study as a springboard for more refined research on these specific topics.

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