University start-up formation and technology licensing with firms that go public: a resource-based view of academic entrepreneurship

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Abstract

Although academic entrepreneurship is a topic receiving some attention in the literature, higher education’s appetite for expanding technology transfer activities suggests that more research is needed to inform practice. This study investigates the effects of particular resource sets on two university commercialization activities: the number of start-up companies formed and the number of initial public offering (IPO) firms to which a university had previously licensed a technology. Utilizing multisource data on 120 universities and a resource-based view of the firm framework, a set of university financial, human capital, and organizational resources were found to be significant predictors of one or both outcomes.

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1. Executive summary

Stimulated by changed external expectations for economic development and internal pressures to generate new sources of income, universities have been rapidly escalating their
involvement in technology transfer, the process of transforming university research into marketable products. In recent years, universities have shown a growing enthusiasm for the more risky forms of entrepreneurial activity, namely, forming start-up companies around a university-developed technology or licensing to small private firms rather than through the traditional commercialization route with large public companies. Although high-profile failures, such as the Seragen case at Boston University are well known, it does not appear to be deterring efforts of this kind. Furthermore, licenses with equity are becoming much more common in the belief that if even a few of the firms in an institution’s portfolio go public, the returns could be enormous.

Within this context of increased emphasis on entrepreneurial activity within universities, our study examines whether particular resource sets are predictive of two separate measures of university technology transfer performance—the number of start-up companies formed and the number of newly public companies [initial public offerings (IPOs)] to which a university had previously licensed a technology. Utilizing a resource-based view of the firm framework and data from 120 universities between 1991 and 2000, a set of five financial, human capital, and organizational resources were tested as possible predictors of each of the outcome variables. These variables included the level of industry R&D funding, the quality of the faculty, the importance of an institution’s patent portfolio, the age of the technology transfer office (TTO), and the availability of venture capital in each university’s geographical area. In addition, we controlled for university endowment and faculty size. Data were obtained from multiple sources, including annual licensing surveys of the Association of University Technology Managers, the ISI University Science Indicators Database, the National Science Foundation, IPO documents, and the Venture Economics Database, among other sources. Results indicated that the level of industry R&D funding, faculty quality, the age of the TTO, and the level of venture capital investment in a university’s metropolitan statistical area were significant positive predictors of both measures of technology transfer performance.

The results provide useful insights for technology transfer practitioners. First, universities that early on established TTOs appear to have been rewarded for their efforts. Our findings suggest that more established TTOs provide an important organizational resource. In addition, our findings are consistent with research that shows that older TTOs are more willing to consider equity arrangements as opposed to focusing exclusively on the more traditional licensing and royalty arrangements. Second, faculty quality (measured by research article citations) was a strong predictor of both of our outcome variables. These findings send a strong signal to university donors and administrators that the recruitment and retention of top research faculty is critical for those institutions seeking entrepreneurial success. Third, R&D investment by industry appears to be a key element in successful technology transfer programs. As universities begin to accept the societal imperative of being an engine of economic development, ever greater collaboration with industry should be expected. Fourth, the positive impact of venture capital funding in the university’s immediate geographical vicinity is important as it supports anecdotal beliefs about perceived locational disadvantages to universities in venture capital poor states. However, given the inconsistency of some earlier findings, more research on venture capital munificence and successful university entrepreneurial activity is needed before this relationship is clearly understood.
2. Introduction

The dramatic increase in the commercial use of university research is well documented in the annual surveys administered by the Association of University Technology Managers (AUTM). In 2000, AUTM reported that 347 new commercial products were introduced to the marketplace based on licensed technologies from 88 universities (AUTM, 2000). New licenses and options increased from 3914 in 1999 to 4362 in 2000. The impact of these licenses on entrepreneurial activity is significant as 626 of the licenses went to 454 start-up companies specifically created to develop and commercialize the results of academic research.

Other surveys have reported similar growth in academic entrepreneurship. For example, Feldman et al. (2002) surveyed 124 research universities and found that the earliest date reported for an equity deal was 1978. By 1992, 40% of the respondents were taking equity in companies licensing their technologies, and in 2000, 70% had participated in at least one equity deal.

To understand the current context in which the university technology transfer phenomenon has emerged, it is necessary to look back in history. Higher education in the United States has experienced periodic calls for greater relevance to society since early in its history. The Morrill Land Grant Act of 1862 and subsequent legislation led to the creation of agricultural extension and mechanical arts programs at specific institutions. Although linkages to business and industry existed and the land-grant institutions were actively engaged in economic-development-related activity, the research engines of America’s colleges and universities really did not move into high gear until World War II. University scientists and engineers played a central role in military research projects, and federal government research funding poured into universities (Rosenberg and Nelson, 1994). With the heightened prestige of American academic science following the end of the war, there was large-scale public and governmental support to sustain university research with much of that funding channeled into defense-related projects. Ultimately, a formalized government policy of support for basic research in higher education was established. The tacit agreement between universities and the federal government up until the late 1970s was that university scientists would be given considerable autonomy to pursue research streams with little requirement of practical application or economic relevance (Etzkowitz et al., 1998).

In the 1980s, there was a dramatic increase in university licensing and other forms of university entrepreneurial activity that most observers attribute to the passage of the Bayh–Dole Act in 1980. This congressional action changed the nation’s intellectual property policy by increasing the incentives to commercialize public research. However, a more evolutionary explanation of the enhanced role universities are playing in innovation is presented by Etzkowitz (1998) and Etzkowitz et al. (1998). The authors explain the emergence of the “entrepreneurial university” as a response to the increasing importance of knowledge in national and regional innovation systems of economic development. They posit that universities are undergoing a “second academic revolution,” incorporating economic development as part of their mission. The universities’ first revolution was to incorporate research as a core function of the enterprise.
Paralleling the increasing involvement of universities in entrepreneurial activities, the study of university technology transfer and academic entrepreneurship has received increasing attention in a number of academic literatures (e.g., Chrisman et al., 1995; Harmon et al., 1997; McMillan et al., 2000; Rosenberg, 1992; Zucker et al., 2002). This body of work has been helpful for framing the topical domain and understanding various processes associated with its conduct (Brett et al., 1991; Matkin, 1990); however, there remain many significant gaps in the literature. Only recently have some researchers begun to expand their study of performance outcomes beyond patents, licensing numbers, and licensing incomes (see e.g., Bray and Lee, 2000; Feldman et al., 2002).

Traditionally, the mechanism by which a university has developed and commercialized a technology has been via the licensing of an intellectual property to a large, established company who ultimately develops the technology into a saleable good. The firm typically makes an up-front payment for the license and commits to making additional royalty payments as a percentage of product sales. A growing trend among universities, however, is to pursue riskier paths for technology transfer through the formation of start-up companies or licenses with young, unproven firms (Steffensen et al., 1999). These alternative commercialization routes represent university efforts at enhancing revenue streams (Bray and Lee, 2000), more effectively aligning university–firm interests, and increasing external prestige and legitimacy (Feldman et al., 2002). Some universities envision themselves as engines of economic development by being associated with what they hope will be the next Xerox or Polaroid corporation, companies built on university-born inventions (Matkin, 1990).

While the potential for substantial financial and reputational returns are considerable with start-up companies, the chances of failure are also increased, particularly for technologies that require long product incubation times and large amounts of capital. Consider, for example, the case of Boston University and its promising start-up, Seragen, which was built around a new cancer drug therapy. In the early 1990s, the University poured more than US$85 million into the firm, at one point almost a fifth of its endowment, convinced that the firm would create enormous profits. However, as is the case with many start-ups, the expected jackpot failed to materialize and the University lost over 90% of its investment (Barboza, 1998).

The risks notwithstanding, high-profile success stories involving the commercialization of university inventions, such as Vitamin D technologies at the University of Wisconsin, the Cisplatin cancer treatment drug at Michigan State University, and Gatorade at the University of Florida continue to drive universities to expand their licensing portfolios and to include unproven start-ups and small, privately held companies (Riley, 1998). Ironically, this growth is occurring despite limited research on technology transfer among these types of firms. Specifically, relatively little work has investigated factors that might explain university differences in start-up company formation (Brett et al., 1991) or explored university experiences with companies that go public, a crowning achievement for a university seeking to advance its reputation as a catalyst for economic development or to generate financial returns through the sale of company stock that it might hold.

The purpose of this study is to address this research gap by investigating the effects of particular internal and external resource factors on the performance of universities in terms of (1) the number of start-up companies formed and (2) the number of newly public companies
to which a university had previously licensed a technology. Utilizing the resource-based view of the firm as a theoretical basis for the research, we hypothesize that particular resource factors are useful predictors of university performance for these two outcomes of technology transfer activity. The financial, human capital, and organizational resource factors examined in our study are the following: financial—industry R&D and venture capital munificence; human capital—faculty quality; and organizational—patent portfolio importance and age of the TTO. We also control for the effects of endowment and faculty size.

The remainder of this study is organized into several sections. In the following section, we argue that the resource-based view of the firm is appropriate for the university context. We summarize the literature and present our hypotheses. We then describe our research methodology and present our results. Finally, we present our discussion, the limitations of our study, and opportunities for future research. The findings provide helpful insights to universities as well as researchers pursuing inquiry in this fertile territory.

3. Theoretical framework and hypotheses

One theory within the strategic management and entrepreneurship literature that has received considerable attention in recent years is the resource-based view of the firm (Connor, 1991). Although the resource-based view of the firm was largely developed from studies of the for-profit sector, its application in higher education is useful for sharpening our understanding of organizational phenomenon, such as technology transfer that occurs there. First, conceptualizing of universities as being in a competitive environment with their peer institutions is appropriate, given current realities. Institutions of higher education have been characterized as confronting revolutionary change (Kennedy, 1995). Universities compete for research funds, star faculty, and for top-quality students, at least among institutions seeking to advance their reputations for excellence. The competition for these financial and human capital resources has become especially sharp in light of more institutions seeking limited federal research dollars, cannibalizing each other’s top faculty, and increasingly relying on merit aid to attract the brightest students. Public universities also must compete more for a reduced pool of state funds. Furthermore, a culture of competition has also emerged attributable to annual rankings published by high-profile news magazines, such as U.S. News and World Report (McDonough et al., 1998). Thus, while higher education may eschew characterizing itself as being part of a “market” or in competition like for-profit firms, the reality is that the environment has become increasingly competitive and market-like (Zemsky et al., 1997).

Researchers using a resource-based view of the firm have, in general, grouped resources into the four categories: financial, physical, human capital, and organizational (Barney, 1997). Of particular interest to this study is the research identifying important resources for entrepreneurial activity, such as would occur with university technology transfer. Some of the unique resources identified have included expert knowledge and scientific capabilities (Deeds et al., 1997; Finkle, 1998) as well as access to important personnel, information, and support structures (Flynn, 1993; Mansfield and Lee, 1996). In addition, researchers have
found a positive relationship between university research and the creation of new products and processes by high-technology industries (Mansfield and Lee, 1996) as well as birth rates of new organizations (Bania et al., 1993; Flynn, 1993).

Given the tenets of the resource-based view as applied to contemporary research universities, certain resource assets may provide a university with technology transfer performance advantages. In this study, we examine five potentially critical resources and hypothesize that each may be a significant predictor of start-up company formation and the number of newly public companies to which a university had licensed a technology.

3.1. Industry R&D revenue

Financial resources are critical for conducting research, especially in the sciences from which many of the technologies being commercialized emerge. Since 1996, institutions have invested a staggering US$3.1 billion in new research space and US$1.3 billion in repairs and renovations (National Science Board, 2000). The ability to obtain funding to support a laboratory has virtually become a prerequisite in today’s university (Etzkowitz et al., 1998).

Industry funding of university R&D increased from US$630 million in 1985 to US$1.896 billion in 1998 (National Science Board, 1998). Although considerably smaller in overall terms in comparison to federal sources, industry-sponsored R&D is one of the fastest growing sources of R&D funding for university research (National Science Board, 1998). Furthermore, although still relatively small in percentage terms, it is an important source of revenue for research universities, and its high emphasis on supporting applied research as well as for generating targeted outcomes suggests that it might stimulate considerable technology transfer activity.

Industries are willing to invest R&D into universities for a variety of purposes. For example, it could be to sponsor a drug trial, to have a particular kind of research conducted for which the company is ill equipped to do, or even for legitimacy purposes on a prototype the firm has already developed. In addition, access to talented students for future job placement is enhanced through linkages with faculty (Rossner et al., 1998; Bozeman, 2000). Furthermore, companies increasingly desire a more collaborative relationship with academic scientists, one in which the professor becomes involved in helping set the strategic direction of the company as opposed to simply handing over the technology (Etzkowitz, 2000). Finally, in industries, such as biotechnology, companies rely heavily on universities for very basic scientific research (e.g., McMillan et al., 2000).

Previous research on university–industry relations indicates that institutions with closer ties to industry generate greater numbers of spin-offs and exhibit more entrepreneurial activity, such as faculty consulting with industry, faculty involvement in new firms, and faculty and university equity participation in start-up firms (Cohen et al., 1998; Roberts and Malone, 1996). In an examination of 11 case studies from Columbia University and Stanford University, Colyvas et al. (2002) found that in all but one case, the researchers involved were members of a network of scientists that included industry professionals. In the single case in which there was no academic and industry scientist linkage, the technology was never transferred. Informal relationships and knowledge flows are
enhanced through the formal institutional ties that have been created through industry R&D centers.

Less obvious, is the effect that industry R&D has on the university’s culture. Historically, there has been some resistance by university faculty to commercial activity (Lee, 1996), and much of the research on university technology transfer has focused on the culture of the university (Bozeman, 2000). Through involvement in industry-sponsored R&D projects, a university begins to establish an entrepreneurial tradition (Etzkowitz et al., 1998). Illustrating this point, Mansfield’s (1995) study of 66 firms in seven major industries as well as of 200 academic researchers found that university-based researchers generally received more government versus industrial funding for their projects when they were at an early stage of development. As a project matured, however, industrial support began to grow in importance as a research idea began to evolve into a bona fide product. Additionally, faculty became more involved as industry consultants. Thus, it may be that when faculty increase their linkages with industry, either as consultants or contracted researchers on a specific commercially oriented project, they develop a stronger entrepreneurial perspective. It is reasonable to assume that as a university accepts greater amounts of industry funding, the attitude of faculty members and the university as a whole shifts away from the historical view of money as inappropriate. Evidence of this is seen in some university departments in which there is increasing importance attached to raising outside research funding in faculty promotion and tenure decisions.

Based upon the evidence cited above, it is likely that industry R&D represents a critical financial resource to universities as would be predicted by the resource-based view of the firm. Therefore, we hypothesize the following:

Hypothesis 1a: The level of industry research funding received by an institution will be positively related to the number of start-up companies formed.

Hypothesis 1b: The level of industry research funding received by an institution will be positively related to the number of IPO companies to which a university had licensed a technology.

3.2. Faculty quality

A critical human capital resource for the development of sophisticated and cutting-edge technologies is access to persons with expert knowledge and talent. University faculty are a primary source of this expertise. However, judging by the fact that institutions do not tend to make radical jumps in published rankings of institutional quality, even over a multiyear period, attracting and retaining a high-quality faculty require considerable time, effort, and financial investment. Hence, it is a likely source of competitive advantage.

Previous research on the value of university researchers provides evidence of this fact. First, research on academic science has provided strong evidence of the importance of faculty for national innovation (Bozeman, 2000; Narin et al., 1997). Higher education and its faculty are uniquely suited to pursue the basic kinds of research that have led to numerous
technological advances (Rosenberg and Nelson, 1994). Second, a significant relationship between the reputation of university scientists and various measures of firm performance has been identified. Deeds et al. (1998), for example, found that university scientists’ talent was a significant predictor of IPO performance of biotechnology companies. Zucker et al. (1998) found a significant relationship between the reputation of university scientists and the number of products in development or on the market as well as the employee size of the company. Finkle (1998) found that biotechnology companies in which the CEO was a former university professor performed better than firms where the CEO was not a former professor. Furthermore, commercialization activity is not limited to disciplines with historically strong ties to industry. Innovations have been commercialized out of a wide range of disciplines in both the pure and applied sciences with some of the most noteworthy ones emerging from the information technology and computer science areas (National Science Board, 2000).

Given this evidence, then, a university that has built a high-quality faculty, something that takes considerable time, effort, and resources, will likely be more successful in their technology transfer efforts than will a university with a faculty of lesser quality. Hence, we hypothesize:

**Hypothesis 2a:** The quality of a university’s faculty will be positively related to the number of start-up companies formed.

**Hypothesis 2b:** The quality of a university’s faculty will be positively related to the number of IPO companies to which a university had licensed a technology.

### 3.3. University patents

While patenting is no guarantee that a university-developed technology has future marketability or that it will even get developed into a product, it does represent a primary tool for safeguarding its future potential. Obtaining patents also signals to important outsiders that an institution is serious about commercialization and recognizes the needs of for-profit firms because the university was willing to invest the necessary time, effort, and expense in obtaining patents. As a result, established firms may be more interested in obtaining the technology. In the context of start-ups, venture capitalists and persons with management expertise may also be attracted to the possibilities of a patented technology and seek to invest or become involved in its development (Bell and McNamara, 1991).

Previous research on patenting indicates that they can be a valuable organizational resource for competitive advantage and predictive of firm performance (e.g., Deeds et al., 1999; Zahra and Bogner, 1999). A valuable line of emerging patenting research, however, has focused on the differences in quality or importance of patents rather than simply the quantity produced by a given organization (Henderson et al., 1998; Mowery et al., 2002). Some of this work has focused on the degree to which university patenting stimulates future patent activity, with some evidence that it declined during the late 1980s (Henderson et al., 1998) but has been rising in more recent years (Mowery et al., 2002). Other research has suggested that a focused patenting strategy oriented toward basic technologies with broader potential across a range of
fields may result in greater success with licensing to start-ups (Roberts and Malone, 1996) and may serve as a catalyst for later innovations (Henderson et al., 1998). For example, in a recent study of university-based start-ups, Shane (2001) found that universities with patents that had greater domestic and international patent class coverage as well as subsequent patent citations were highly predictive of a technology being developed via the formation of a start-up firm.

Considering the fact that over its lifetime, patent costs can run from a low of around US$20,000 for a domestic patent to a high of US$250,000 or more for a worldwide patent, the decision to patent is a financially risky one for a university and hence, not easily taken. Furthermore, the higher quality or more important patents, defined as the more basic ones, may be especially valuable and difficult to imitate. Hence, as the resource-based view might predict, universities that possess more of these kinds of patents would likely outperform universities less well endowed with this organizational resource. As such, we hypothesize:

**Hypothesis 3a:** University patent importance will be positively related to the number of start-up companies formed.

**Hypothesis 3b:** University patent importance will be positively related to the number of IPO companies to which a university had licensed a technology.

### 3.4. Technology transfer office

TTOs represent an important resource to university research faculty. Professionals who work in university TTOs must understand both the culture and function of the academic research enterprise as well as that of the industry sector, using their expertise to put together licensing deals. Given that faculty typically know relatively little about the business of technology commercialization but usually have a high degree of psychological ownership for their inventions, TTO professionals are key players in the commercialization of a technology, often in their role as arbiters between the higher education and industry cultures.

Following passage of the Bayh-Dole Act in 1980, there began a dramatic increase in the establishment of TTOs and in turn, university licensing activity. AUTM surveys report that approximately 20 universities had TTOs in 1980. That number had grown to 200 by 1990, and by the turn of the century, nearly every major university had a TTO (Colyvas et al., 2002).

The learning curve for new TTO personnel is steep as they may be unfamiliar with the faculty and industrial networks important for finding licensees (Thursby and Thursby, 2002). Thus, institutions with older TTOs would be expected to have developed superior skill sets for managing the commercialization enterprise, and hence, also predicted to enjoy higher performance levels based on this organizational resource. The technology transfer literature suggests that institutions with older offices often outperform those with newer offices, perhaps due to the longer time period needed to develop the resource of specific skill sets useful to facilitating technology transfer (Matkin, 1990; Roberts and Malone, 1996).
As TTO offices gain experience, they are more willing to consider equity in start-up companies. In the 2000 AUTM survey, an equity interest was a part of 82% of the start-up company deals, which was up substantially from the previous year. Bray and Lee (2000) conducted interviews with licensing managers at 10 TTOs. They found that universities that took equity had older TTOs, leading them to conclude that an established TTO is more likely to consider taking equity than would a young TTO with pressure from the university to become self-supporting. The younger TTOs focused primarily on royalty income, but as the TTO gained experience, its personnel were more willing to consider equity. Bray and Lee’s results were consistent with Feldman et al.’s (2002) study examining the conditions under which universities adopt equity-based transfer mechanisms. They found a positive relationship between the age of the TTO and the university’s use of equity as a percentage of intellectual property transactions.

In summary, an experienced TTO is an important organizational resource to universities engaged in all forms of technology transfer. The greater willingness of older TTOs to accept an equity arrangement would be especially important in the formation of start-ups, as the use of equity would most likely be used in start-up deals. Therefore, we hypothesize that:

**Hypothesis 4a:** The age of the technology office will be positively related to the number of start-up companies formed.

**Hypothesis 4b:** The age of the technology office will be positively related to the number of IPO companies to which a university had licensed a technology.

### 3.5. Venture capital munificence

Venture capital is a valuable financial resource to many of the types of companies that come out of universities based on their capital-intensive nature, and in the case of biotechnology firms, their long time frame to profitability (Lerner, 1994). Specifically, university start-ups benefit from the financial capital provided, but often also from the management or advisory expertise provided by venture capitalists (McMillan et al., 1987).

The limited quantitative research investigating venture capital effects on university technology transfer has been conflicting. While one study found that venture capital abundance in a region did not predict university start-up formations (Di Gregorio and Shane, 2001), another found that linkages with venture capitalists and angel investors was more likely to lead to success, especially as it related to reaching an IPO stage (Shane and Stuart, 2002). Qualitative research on university start-up companies, however, has been more universally affirming about the important role venture capital plays in the ultimate success of a new university venture (Cawood, 1991) and how regional differences in venture capital availability may influence a university’s level of success with at least start-ups (Roberts and Malone, 1996).

Other studies of young companies in general also affirm the importance of venture capitalists both as a resource for financing as well as for advice on business management and
strategy (Fried et al., 1998; Pratt, 1995; Sapienza, 1989). Furthermore, given that most university start-ups are located within close proximity to the parent institution (AUTM, 2000), the likelihood of a start-up reaching an IPO stage may be enhanced if their region happens to be robust in venture capital firm resources (Powell et al., 2002).

Despite the somewhat conflicting research regarding the performance advantages for universities located in venture robust regions, there is substantial evidence to suggest that the venture capital available in the region where a university is located should predict the number of start-ups formed and licenses with newly public companies. Therefore, we hypothesize that:

**Hypothesis 5a:** The venture capital munificence of a university’s geographical area will be positively related to the number of start-up companies formed.

**Hypothesis 5b:** The venture capital munificence of a university’s geographical area will be positively related to the number of IPO companies to which a university had licensed a technology.

4. Methodology

4.1. Sample

Data were collected from multiple archival sources on 120 institutions classified as “research extensive” and “research intensive” universities in the Carnegie Classification System. These institutions are the ones that are the most engaged in doctoral education and research activity in this country. Furthermore, the bulk of university commercialization effort is centered on institutions from these two classifications.

4.2. Independent variables

4.2.1. Industry R&D revenue

The industry R&D revenue variable is continuous and represents average annual industry R&D revenues realized by an institution over the 3-year period 1993–1995. A multiyear average or total figure time frame was used for this and other variables due to year-to-year fluctuations in the data. The data for this variable was obtained from the National Science Foundation’s annual surveys of academic research and development expenditures.

4.2.2. Faculty quality

The total number of citations that each university received over the 3-year period 1993–1995 was used to operationalize faculty quality. The data for this continuous variable was collected from ISI’s University Science Indicators Database. ISI currently indexes approximately 5500 journals in the sciences, 1800 in the social sciences, and 1200 in the arts and humanities, all of which were peer reviewed.
4.2.3. Patent importance

The patent importance variable in this study is built from the work of Hall et al. (2001) and obtained from their National Bureau of Economic Research Patent Citations Data File and their variable called generality. Generality is an index measure of the degree of patent basicness as captured by how impactful a particular patent is on future innovation across a range of patent fields and is more robust than simple patent citation counts. Generality is operationalized as:

\[
\text{Generality}_i = 1 - \sum_{j}^{n_i} S_{ij}^2,
\]

where \( S_{ij} \) denotes the percentage of citations received by patent \( i \) that belongs to patent class \( j \), out of \( n_i \) patent classes. Generality scores can range from 0 to 1 with higher scores indicating greater impact on subsequent patent activity.

Previous work using this measure has demonstrated its validity as a measure of patent importance in terms of impact on later innovation in a field (Henderson et al., 1998). We utilized this measure to construct our actual patent importance variable, an average generality score across the portfolio of a university’s patents between 1993 and 1995.

4.2.4. Age of TTO

The age of the TTO was operationalized as the number of years that the office had at least 0.5 full-time equivalent (FTE) of dedicated professional staff. The data were obtained from the 1996 AUTM licensing survey.

4.2.5. Venture capital munificence

This continuous variable was operationalized as the total venture capital dollar investments made within the U.S. Census Bureau’s Metropolitan Statistical Area (MSA) of a given university between the years 1995 and 1999. The venture capital investment data was drawn from the Venture Economics Database.

4.3. Dependent variables

4.3.1. Start-up companies formed

The first measure of university technology transfer performance is the number of start-up companies formed. This continuous variable represents the total number of start-ups formed by a university during the period 1996–2000 and was drawn from the AUTM licensing surveys. A 4-year range of time was chosen for the institutions of interest as a more accurate reflection of their true activity than a 1-year measure. Furthermore, although previous research has suggested an average 7-year time lag between an academic invention and an actual commercial application (Mansfield, 1995), we felt a shorter one was appropriate for this study given that our dependent variables were reflective of company rather than product milestones.\(^2\)

\(^2\) Many companies are started with only prototype ideas and many companies IPO with technologies that are still under development. Hence, we felt that Mansfield’s time frame would be too long for what we were studying.
4.3.2. IPO companies to which a university had licensed a technology

The second measure of university technology transfer performance is the number of newly public companies (IPOs) to which a university had previously licensed a technology. For ease of reading, we refer to this variable as “IPO licenses” throughout the remainder of this paper. For the purposes of this continuous variable, the total number of companies that made an IPO in which a university had a licensing deal between May 1996 and June 2000 was used. The initial time frame was chosen because May of 1996 was the first time that the Securities and Exchange Commission (SEC) required all firms making an IPO to file a prospectus on-line. Hence, the on-line data would be reflective of all IPOs made from this point. A 4-year time frame was chosen to maximize the number of firms in the dataset, thus making it more reflective of an institution’s actual involvement with IPO firms, as the number of these types of firms for each institution was relatively small (ranging from 0 to 22).

Data for this variable was obtained from the SEC’s Edgar Database as well as a specialized search engine, 10kwizard.com, specifically designed to do keyword searches of Edgar data. To verify the accuracy of our work, the results were triangulated with data collected by Recombinant Capital, a company that closely follows the biotechnology, medical device, drug, and information technology industries and lists companies with licensing deals with universities. Finally, the web pages of all of the institutions in the sample were searched because some institutions are posting the names of their start-up companies that have gone public. These supplemental analyses revealed the accuracy of the data mined from the Edgar database.

4.4. Control variables

Two resource variables were included as controls: university endowment and faculty size. The university’s endowment was operationalized as the value of a university’s endowment portfolio in 1995. The faculty size variable represented the total number of full-time faculty at the institution in 1995. The data points were obtained from the National Center for Educational Statistics IPEDS Database. As is commonly done in strategy and entrepreneurship research, these variables controlled for potential wealth and size of employee base effects.

5. Results

Given that our dependent variables were count data with a moderate number being zeros, poisson or negative binomial regression would be the appropriate statistical analysis tools to use (Cameron and Trivedi, 1998). A goodness of fit test rejected the poisson distribution assumption in both models, indicative of overdispersion in the data. Hence, negative binomial regression was selected for analyzing the data.

Table 1 presents the descriptive results including a correlation matrix. The average number of start-up companies formed was 10.9 while the average number of IPO companies to which a university had licensed a technology was 2.2. Universities had an average of US$8.86
million in industry-sponsored research, and an average 4-year total venture capital investment of US$841 million in their MSA. The average age of TTOs was 13.9 years.

To test for collinearity violations, variance inflation factors were computed for each variable (not shown), all of which were under 1.6, well below the concern level of 10 (Von Eye and Schuster, 1998). Furthermore, a series of regression model pairs were run, in which each independent variable with a correlation at or above .4 was included and then subsequently excluded from the models to see if the regression coefficient results were substantively effected. No differences were found, indicating the absence of excessive collinearity.

Table 2 presents the results of the regression analyses. The two independent variables, faculty quality and venture capital munificence, were log transformed due to skewness in the data. Two regression models were run, one with the start-ups formed as the dependent variable and the other with the IPO companies as the dependent variable. The regression results indicate that a university’s financial, human capital, and organizational resources do

### Table 1
Means, standard deviations, and correlations

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Start-ups formed</td>
<td>10.9</td>
<td>13.32</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2) IPOs</td>
<td>2.2</td>
<td>3.16</td>
<td>.78</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(3) Endowment</td>
<td>US$463</td>
<td>US$752</td>
<td>.40</td>
<td>.55</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4) Faculty size</td>
<td>958</td>
<td>475</td>
<td>.27</td>
<td>.19</td>
<td>.14</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(5) Industry R&amp;D</td>
<td>US$8.86</td>
<td>US$8.91</td>
<td>.62</td>
<td>.58</td>
<td>.22</td>
<td>.34</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(6) Faculty quality</td>
<td>22,974</td>
<td>20,205</td>
<td>.63</td>
<td>.77</td>
<td>.50</td>
<td>.32</td>
<td>.49</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(7) Patent importance</td>
<td>0.37</td>
<td>0.15</td>
<td>.15</td>
<td>.10</td>
<td>.06</td>
<td>-.09</td>
<td>.06</td>
<td>.19</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8) TTO age</td>
<td>13.9</td>
<td>11.9</td>
<td>.52</td>
<td>.45</td>
<td>.14</td>
<td>.17</td>
<td>.30</td>
<td>.38</td>
<td>.09</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>(9) VC munificence</td>
<td>US$841</td>
<td>US$1.75</td>
<td>.45</td>
<td>.57</td>
<td>.37</td>
<td>-.13</td>
<td>.14</td>
<td>.53</td>
<td>.16</td>
<td>.20</td>
<td>1.00</td>
</tr>
</tbody>
</table>

Correlations at or above .30 are significant at \( P < .01 \); those at or above .19 are significant at \( P < .05 \). \( n = 120 \).

### Table 2
Results of negative binomial regression analysis

<table>
<thead>
<tr>
<th>Variable</th>
<th>Model 1: startups (( n = 120 ))</th>
<th>Model 2: IPOs (( n = 120 ))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endowment (US$ millions)</td>
<td>1.00 (.001)</td>
<td>1.0* (.001)</td>
</tr>
<tr>
<td>Faculty size</td>
<td>1.00(^i) (.001)</td>
<td>1.0 (.001)</td>
</tr>
<tr>
<td>Industry R&amp;D (US$ millions)</td>
<td>1.03**</td>
<td>1.02** (.005)</td>
</tr>
<tr>
<td>Log faculty quality</td>
<td>2.91*** (.296)</td>
<td>7.95*** (.284)</td>
</tr>
<tr>
<td>Patent importance</td>
<td>2.04 (.518)</td>
<td>.54 (.542)</td>
</tr>
<tr>
<td>TTO age</td>
<td>1.02*** (.006)</td>
<td>1.01* (.005)</td>
</tr>
<tr>
<td>Log VC munificence</td>
<td>1.18* (.069)</td>
<td>1.19* (.084)</td>
</tr>
<tr>
<td>Wald ( \chi^2 ) (degrees of freedom used)</td>
<td>144.17*** (7)</td>
<td>145.78*** (7)</td>
</tr>
</tbody>
</table>

The coefficients are exponentiated betas. Standard errors are in parentheses.

\* \( P < .05 \).

\** \( P < .01 \).

\*** \( P < .001 \).

\(^i\) \( P < .10 \).
have a significant affect on the formation of start-up companies as well as the number of IPO licenses. Four of the five resources that we studied appear to be a significant influence on both of these measures of technology transfer performance.

More specifically, Hypotheses 1, 2, 4, and 5 were supported while Hypothesis 3 was not supported. The level of industry R&D revenues received by a university, the quality of their faculty, the age of the TTO, and the level of venture capital investment in the university’s MSA are all important predictors of start-up formation and the number of newly public companies to which a university had previously licensed a technology. The quality of an institution’s patent portfolio was not a significant resource factor for either of our performance models.

6. Discussion

The purpose of this study was to investigate the effects of resource factors on the technology transfer performance of universities in terms of start-up company formation and licenses held with companies that make an IPO. The results indicate a set of financial, human capital, and organizational resources that are predictive of these measures of technology transfer performance.

The first of these resources, industry R&D revenues, was positively predictive of both the number of start-ups formed and the number of IPO licenses. While it is clear from our analysis that industry R&D revenues do impact performance, the why is not addressed in our study. Besides the obvious financial impact, it is likely that industry R&D activity helps to stimulate a culture of entrepreneurship within the university. Faculty engaged in industry-sponsored entrepreneurial activity share their experiences with or involve other faculty in their funded research. As a result, the culture may be altered because culture is a reflection of the shared experiences of the members of the organization. Furthermore, the investment by industry into numerous university research centers likely fosters an entrepreneurial spirit within the university itself, and builds industry/university linkages that may form the basis for further collaborative endeavors.

As a practical matter, in the fiscally constrained financial environment in which universities operate today, the negative attributes associated with industry-sponsored research have diminished. In fact, for some disciplines, promotion and tenure decisions are heavily weighted on a professor’s ability to attract outside sources of funding. Our findings also lend support to the new models of the university (e.g., Etzkowitz et al., 1998) in which the university is much more receptive to industry relationships and entrepreneurial activities.

The slack resources that would likely be associated with higher levels of industry R&D have some additional implications. Specifically, slack resources provide universities with greater flexibility to choose the more risky time and personnel intensive start-up route to commercialization rather than the traditional large firm path. Furthermore, doing so appears to result in greater rewards, in this case, more successful licensing to firms that IPO. Our results, then, suggest that industry-sponsored research does stimulate business growth, for
which society and the institution benefit in terms of economic development and equity returns, respectively.

The second noteworthy finding was the strong predictive nature of faculty quality in both models. This result suggests the paramount importance of building and maintaining a base of faculty leaders in their fields and carefully working with them on leveraging their research into commercially viable products. Although our study did not explore differences among particular disciplines, previous research on just science and engineering faculty found similar results (Powers, 2000). Given the culture of academia and the controversy surrounding the efficacy of a commercialization mission for higher education, our results highlight the centrally important role played by faculty and how ignoring this resource can undermine university–industry partnerships for technology transfer.

Patent importance did not prove to be predictive. The importance of a university’s patent portfolio does not propel either of our performance measures, suggesting that numerous other forces may inhibit an otherwise highly innovative technology. Our results may be interpreted by some as suggesting that picking technologies for commercialization may be as much about educated guesses as it is about rational evaluative processes leading to a “right” choice. However, we would caution that our study examined only one patent measure. Our results could have been very different had we chosen to examine the impact of patent citations or some other patent-related measure. The patent strategy of a university may vary tremendously. For example, some universities may merely pursue a numbers game, while other universities may concentrate on patenting technologies applicable to a specific industry, such as optics, biotechnology, or petroleum. In addition, our study examined only two measures of university entrepreneurship, and these measures may not be as impacted by the quality or importance of a university’s patent portfolio as might such measures as the number of licenses or licensing income received. Additionally, it may be that the lag time we chose was not long enough to detect an effect that is in fact present. As TTOs begin to explore mechanisms of technology transfer beyond traditional licensing and royalties, additional research examining the relationship between varying performance outcomes and different attributes of the university’s patent portfolio is merited.

The age of the TTO was a significant predictor of start-ups formed and the number of IPO licenses. Considering the complexity and time-intensive nature of technology transfer practice (e.g., working with faculty inventors, making decisions on whether or not to patent a technology, connecting faculty with industry clients, deciding upon a strategy for marketing a technology to outside firms, and working with venture capitalists and management of start-up companies), our results suggest that older, more established TTOs appear to have better developed the needed competences to more effectively facilitate technology transfer.

When one considers the specific measures of technology transfer performance used in our study, i.e., start-ups formed and number of IPO licenses, previous research by Bray and Lee (2000) and Feldman et al. (2002) provide interesting insights into our finding. Their research showed that as TTOs become older and more established, they also become more willing to consider other mechanisms of technology transfer beyond the traditional licensing and royalty arrangements. Initially, TTOs concentrate on licensing deals with established, often public, companies that provided up-front fees and ongoing royalty payments because start-up
companies were considered risky and lacking in cash. An equity deal was considered to be a last resort (Feldman et al., 2002). However, because start-ups are nearly always starved for cash, equity is the most likely mechanism under which it is possible for the university to strike a deal. From their interviews with TTO personnel, Feldman et al. (2002) learned that the perception of equity is no longer negative. They surmised that the increased experience of TTOs with traditional licensing led to a better understanding of its limitations and a downward revision in expectation of its revenue-generating potential. In contrast, they began to understand the potential financial benefits of equity, the opportunity to better align the interests of the university and the firm, and the potential prestige and legitimacy for both the university and the licensee company. Our finding that universities with older TTOs had higher numbers of start-ups and IPO licenses is consistent with the technology transfer research examining attitudes of TTOs toward equity. By virtue of the fact that the firm is a start-up, the university is more likely to have accepted equity as part of the technology transfer deal. Our findings suggest that for our sample, older TTOs have demonstrated a positive attitude toward equity deals, and either through their willingness to accept equity or their increased competencies, have been able to assist their universities in a greater number of start-up formations. Universities with more start-up companies in their portfolio would then by definition increase their chances for expanding their portfolio of licensee companies with the potential for an IPO.

The final resource examined involved the venture capital munificence variable. We found evidence that universities located in MSAs with more abundant venture capital investment formed a greater number of start-ups and had a greater number of IPO firms than did universities located in MSAs where venture capital was less abundant. Much anecdotal and popular press evidence suggests that local venture capitalists are facilitating universities in start-up formation by investing funds in them and assisting to identify persons with the necessary management expertise to run the companies. In our observations of, and interviews with, university technology officers and start-up CEOs, we have found this to be true as well.

As previously noted, prior research on venture capital effects have been somewhat conflicting. Given the variability in venture capital investment strategy and the enormous fluctuation in venture disbursements in recent years, it may be that venture capital effects are more complex than have been investigated up until this point. In an earlier version of this paper, for instance, we had explored a lengthier time lag with this variable and found no effect as had Di Gregorio and Shane (2001) in their study. One of our reviewers suggested that the impact of venture capital would have a more immediate impact on start-ups than the lag we had used. When we reformulated the variable to a shorter lag, we found a significant and positive relationship for both of our performance variables. Thus, it appears that further research into venture capital and university technology transfer remains a robust area of inquiry.

7. Limitations

While this study provides new insights into the experience of universities with their technology transfer programs, it is not without its limitations. A first potential shortcoming of
the study centers on the operationalizations of particular variables. For example, the faculty quality measure was calculated from citation data. While citation data is objective, relevant to our topic of research, and certainly more methodologically sound than such data as popular press rankings, citation data is still an imperfect faculty quality measure. In addition, as business school and other nonscience or engineering faculty become more active in technology transfer activities, it is increasingly difficult to judge which discipline areas are relevant for study. We decided to adopt a broad approach for our study, measuring citation data for all faculty within the university. It is clear, though, that more limited operationalizations have legitimacy as well.

Another variable operationalization that merits discussion is that of patents. Much of the research on patenting has utilized simple patent counts. However, given that patent quantity measures are inherently noisy (i.e., patents vary considerably in terms of their quality or value), we chose to utilize a patent quality measure, an operationalization that is beginning to emerge in the literature. Yet, other quality measures could have been used, such as citations received, citations made, or patent protection coverage.

A second shortcoming is the study’s cross-sectional design. While this concern was alleviated somewhat by using multiyear measures for variables, it nonetheless does not fully capture how performance has changed over a period of years. Temporal considerations are a potentially important issue considering the time horizons involved in developing a technology, licensing it, and seeing it produce an income stream.

A third limitation is that the study does not address any of the cost effectiveness issues that are obviously of additional interest. For example, the study showed that age of the TTO was directly related to performance. However, the costs of establishing an office may not outweigh the benefits. Similar cost issues are relevant to the decision of whether or not to patent.

Finally, as with most research projects using secondary data, some additional information could have been obtained via an institutional survey. For example, information on key policies, such as how technology transfer activity figures into tenure and promotion or if faculty can take leaves of absence to work on commercial projects would add richness to our findings.

8. Opportunities for future research

Based on the research findings from this study, a number of useful streams of future research are evident. First, a content analysis of the IPO documents searched for this study would reveal valuable information on such issues as the nature of equity positions by universities, the kinds of licensing arrangements with universities, and insights about the faculty entrepreneur. A second useful area of inquiry would involve the post-IPO performance of firms that hold university licenses. For example, are there any aspects of universities that may predict 1-year stock performance? Logic would suggest that over time, institutional effects diminish, but no study has actually sought to empirically test this proposition. Finally, the systematic study of university entrepreneurship is relatively recent. As the knowledge
base increases, researchers should attempt to understand the more complex relationship between variables. For example, we suspect that there are important interactions impacting performance.

9. Conclusion

Using the theoretical lens of the resource-based view of the firm, this research has shown that the level of industry R&D revenues, faculty quality, age of TTO, and venture capital munificence are significant predictors of technology transfer performance. This study also offers useful insights into the planning and execution of technology transfer activities that inform its responsible practice. Given the increased emphasis on universities as engines of economic development, helping faculty and reluctant administrators to understand that a university commercialization mission is not necessarily incompatible with the other important functions of the enterprise could do much to increase their engagement in technology transfer. This study also offers the potential for useful future streams of entrepreneurship research using the unique database created as well as investigations using new or reoperationalized variables. Finally, and perhaps most importantly for the field of entrepreneurship, it builds on previous studies of university entrepreneurial behavior and further highlights the unique but understudied nature of the academic enterprise as a significant source of entrepreneurial activity.

References