WHEN STARS SHINE: THE EFFECTS OF FACULTY FOUNDERS ON NEW TECHNOLOGY VENTURES

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Despite the increasing importance of faculty entrepreneurship to technology diffusion, wealth creation, and economic growth, we know little about the effects that academic faculty turned entrepreneurs have on the performance of new technology ventures. We argue faculty inventors select their most promising projects for commercialization. We further posit that star faculty founders have positive effects on new venture performance, above and beyond that of the average faculty founder. In addition, we develop two contingency hypotheses to unearth specific situations when 'stars shine.' We posit that star faculty founders are able to overcome geographic distance to venture capitalists as well as the disadvantages of not being affiliated with a top research university. We test our hypotheses on a broad sample of 238 university-related new technology ventures at 65 U.S. universities. Copyright © 2012 Strategic Management Society.

INTRODUCTION

The main street view of technology entrepreneurship is a couple of nerds starting a company in the garage or a soon to be trashed rental house in Silicon Valley. Similarly, academic scientists are seen as the scatterbrained professors in the white lab coats in university labs working in obscurity with eager graduate students to publish their research findings in academic journals. In reality, however, these two disparate groups have much more in common than generally assumed (Rothaermel, Agung, and Jiang, 2007; Siegel, Wright, and Lockett, 2007). For the last few decades, many science and engineering professors have eschewed the limits of the ivory tower university and launched new companies often founded on the very technologies they have been studying at university laboratories. Investors, who used to seek transformational discoveries through sponsored research grants and licensing agreements for university-held patents, are now investing directly in firms founded by many of these highly creative academic inventors turned entrepreneurs.

Faculty entrepreneurship is seen as an important contributor to knowledge diffusion from the university to society at large, leading to innovation and economic growth and, thus, employment (Cohen, Nelson, and Walsh, 2002; Mansfield, 1995). Examples of companies founded by university faculty include Bose (the speaker company, out of MIT), Genentech (the first biotechnology company, out of Stanford University and the University of California, San Francisco), iRobot (robot company, out of MIT), Lycos (Internet search company, out of Carnegie Mellon University), SAS (software company, out of North Carolina State University), and SunPower (photovoltaics company, out of Stanford University), among many others. New technology firms are precisely the firms that generate most

of the economic growth and wealth resulting from entrepreneurship (Bhide, 2000).

Engaging faculty in the commercialization efforts of their inventions is clearly critical to success (Jensen and Thursby, 2001). Codified knowledge in licensing agreements is often not enough to succeed, rather the ability to access tacit knowledge is needed. When studying graduation events from the technology incubator at Georgia Tech in a sample of 79 start-ups, Rothaermel and Thursby (2005) found that only faculty with strong ties, proxied by being founders, impacted early-stage performance of the new ventures, while weaker ties such as consulting, had no effect. Studying more than 100 licensing agreements from MIT, Agrawal (2006) finds that direct inventor engagement was critical to successful commercialization because this allowed the licensee to tap into the inventor's tacit and latent knowledge.[1] Even though direct inventor involvement seems to be an obvious strategy given the often early-stage development of university research, Agrawal (2006) also notes that significant heterogeneity exits in regard to direct inventor involvement; a full third of licensees did not directly involve the inventor in the commercialization efforts. Further insights are provided by Murray (2004), who shows through an in-depth study of biotech inventors that academic inventors endow new ventures not only with human, but also with important social, capital emanating from both their participation in the local laboratory network as well as in the larger cosmopolitan network of the scientific community.

It is also important to note that significant heterogeneity exists among faculty inventors. In particular, the seminal research stream by Zucker and Darby demonstrates the substantial impact that star scientists have on the early-stage performance of new ventures. Looking at the commercialization of biotechnology in the 1980 and early 1990s, Zucker and Darby show that star scientists have a direct effect on a number of important new venture characteristics: firm location, time to initial public offering (IPO), dollar amount obtained at IPO, and drugs in development (Zucker, Darby, and Brewer, 1998; Zucker, Darby, and Armstrong, 2002; Zucker and Darby, 2009).

With the exception of some research on Georgia Tech, MIT, and UC-Berkeley start-ups (Agrawal, 2006; Nerkar and Shane, 2003; Rothaermel and

Thursby, 2005; Shane and Stuart, 2002), few studies have tackled the difficult issue of linking faculty entrepreneurship and new venture performance due to a dearth of data. Prior studies tend to rely on no more than a few and often only one premier research university as a sampling frame. Moreover, most prior work focuses on one or a small number of industries, with the life sciences the most common research setting. In contrast, we focus on the role of star faculty founders across a broad sample of 238 new technology ventures drawn from 65 U.S. universities across multiple industries. To more richly motivate our hypotheses we additionally draw on field work conducted with 16 scientists turned entrepreneurs, venture capitalists, and university technology transfer officials.

We study new technology-based firms (NTBFs), which we define as new ventures formed to commercialize a patented invention by a university faculty. We bifurcate NTBFs along the dimension whether the faculty inventor is also a firm founder or not. We advance two direct and two contingency hypotheses. Our starting point is the baseline hypothesis that faculty founders select their most promising projects for commercialization. We further argue that star faculty founders have a positive effect on new venture performance, above and beyond that of the average faculty founder. We then identify two specific contingencies when stars shine. First, star faculty founders are able to overcome the liability of distance for new technology ventures not located in venture capital (VC) dense areas. Second, a star faculty member is able to overcome the disadvantage of not being affiliated with one of the top research universities and, thus, still increase the NTBFs probability of an initial public offering. In a broader conceptual sense, our study makes a contribution within the emerging theoretical framework on microfoundations in strategy and entrepreneurship (Bingham and Eisenhardt, 2008; Bingham, Eisenhardt, and Furr, 2007; Felin and Hesterly, 2007; Rothaermel and Hess, 2007).

THEORY AND HYPOTHESES

Successful commercialization begins with private information that faculty founders are able to exploit. Due to information asymmetry combined with uncertain outcomes, a classic lemons problem arises (Akerlof, 1970), this time in the market for faculty inventions (for a test of the Akerlof model in biotech

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[1] Latent knowledge is knowledge that could be codified but was not due to a lack of incentives (Agrawal, 2006).

new product development, see Pisano, 1997). Given the scientist's opportunity cost, the faculty member will choose only the most promising project among the many that he/she worked on to commercialize through his/her direct entrepreneurial involvement as a firm founder. In contrast, less promising projects will be licensed for others to commercialize or they will be shelved. This selection effect occurs due to private information the inventor has about the quality differences of the underlying projects considered for commercialization. These quality differences are not observable by outsiders but require intimate familiarity of a project, often obtained through years of direct involvement in a laboratory or other research setting.

Several faculty inventors interviewed for this study expressed the importance of the selection effect based on private information when deciding whether to become an entrepreneur: We interviewed a faculty inventor who had prior experience working in the U.S. national labs and had also done quite a bit of consulting before accepting an endowed chair at a major research university. 'I was hired here (at the university) to be an 'entrepreneurial ultrafast optics guy.' I wasn't required to start a company or anything, but once I was here, I realized I had a great device that could be sold to other researchers. Then I invented a much simpler device which had more possible customers.' This faculty then chose the latter project as the most promising to be commercialized through his direct involvement as founder. 'We are able to use high-skilled optics shops to produce a device that automatically aligns the mirrors and other devices needed in optical experiments. This is the basis of my company which was formed in 2001.'

Another faculty inventor in the medical field remembered his entrepreneurial interest early in his career. 'When I was finishing my undergraduate engineering degree, I actually pushed toward academia mostly because I liked the idea of consulting and perhaps starting a company rather than working for an established firm.' Interestingly, this same inventor initially did not file any patents or work toward commercialization. He explains that 'as an assistant professor, I immediately started consulting. It was very quick impact projects with great pay per hour. I didn't file many patents in my first few years because I didn't see the point in filing them if I wasn't planning to do anything with them myself.' However, later in his career, after he got tenure, he moved to a university more supportive of his entre-

preneurial goals and founded a company. Recently, he shared: 'I'm passionate about getting our products successfully out into the market, which was never a key motivator for me as a consultant. I also hope to accrue financial benefits through the firm's success and I have to admit this is a part of my drive to help the firm succeed as a founder that I did not have as a consultant.'

One of the interviews with a highly cited faculty member in electronics gave some insights into his decision to start a company: '. . . as a consultant I participated in design meetings for an Intel circuit. From this experience, they found they liked my new approach to designing circuits and I met with several of their (Intel) key leaders. There was a strong feeling that we should form a company around these circuit design tools. We started it in 1987 and took it public in 1991.'

Taken together, we argue that faculty founders select themselves into the projects with the most commercial promise due to the possession of private information. This selection effect, in turn, has a positive differential impact on the early-stage performance of new technology ventures founded by university faculty turned entrepreneurs.

Hypothesis 1: An NTBF founded by a faculty inventor will have a higher probability of a liquidity event versus an NTBF formed to commercialize a faculty invention, but without the faculty inventor as founder.

Besides this initial selection effect, a subsequent treatment effect is also critical to the success of inventor-founded new tech ventures. In particular, the success of technology commercialization is deemed to be continued scientific involvement of a faculty inventor beyond a licensing agreement (Jensen and Thursby, 2001). The involvement of the faculty inventor is useful particularly because much of the knowledge of commercializing inventions is tacit and, thus, best transmitted through the personal efforts of the inventor (Hess and Rothaermel, 2012; Valli, Kerr, and Mitchell, 2007; Zucker *et al.*, 2002). This type of tacit knowledge has been shown to be difficult to transfer under the best of circumstances (Agrawal, 2006). When looking at the impact of different strengths of ties by faculty inventors, Rothaermel and Thursby (2005) document that only direct faculty involvement as firm founder had a positive effect on early-stage performance. Other weaker ties, such as consulting or informal relation-

ships, were not significant predictors of early-stage venture performance. Thus, there is a growing awareness of faculty founding new ventures to leverage their specialized knowledge into commercial endeavors (Lowe and Ziedonis, 2006).

Several faculty members commented why their direct involvement as firm founder was needed. Here is a typical comment from one: 'Implicitly there is very little information in a university patent or a publication that is helpful in successfully getting an idea to market. That's why I think it's important for me as the inventor and founder to be actively engaged with the firm. My area of engineering is more applied than some others, but in my field of engineering, this is really important.'

One of our faculty interviewees who had founded several firms in the biomedical field had this to say about what benefits the inventor brings into the firm: '. . . to get your product to commercial success relates to the fact that there are a variety of ways to proceed in most of these cases. The inventor has usually tried a whole lot of things that failed. Well, you are not patenting or publishing any of those failures, but that knowledge of knowing what doesn't work is actually very valuable to whoever is making it. They (the firms) don't have to reinvent the wheel and they can save a lot of time and money.'

One of the inventors in the biomedical field was discussing a recent technical problem his firm was facing and his role in helping to resolve it: 'An example is we have a new product that we did the basic science for a few years ago, but the firm's engineers were having trouble with designing the materials into the applications. I've just had a meeting with the team at the firm and provided *substantial guidance* on ideas that may work and why they might work because the material is complicated but I can still have a *big impact on our design* and therefore commercializing process.' He goes on to speak about his broader role at the start-up: '. . . at my firm, I have an ownership position now for solving the problem. I have an actual vested interest in solving the problems here. I am *intimately involved* because I want to get the problem solved.'

One example we found particularly striking through our interviews is germane to the value of tacit and latent knowledge embodied within a person (Agrawal, 2006). The new venture in the medical field has a product currently out in the market and is receiving feedback from lead users (von Hippel, 2006). The faculty founder stated: 'We have medical doctors come up to us all the time with great new

ideas to use our material. I tell them all "if you think it's a great idea, we need you to give us 100 hours of your time this year to work on it. We need your time. Your idea has no value to us but your idea *plus YOU* may be very valuable." '

Although it is fairly well established in the literature that faculty inventors are critical to continuous commercialization of inventions, scientists and engineers are a heterogeneous group (Hess and Rothaermel, 2012). Some have clearly been recognized as amazingly productive in their research publications and citations. Building upon the work by Zucker and Darby on star scientists, we suggest that some intellectual human capital will be more useful than others to the early outcomes of technology ventures (Zucker and Darby, 2009; Zucker *et al.*, 1998; Zucker *et al.*, 2002). A professor who is highly relied upon by his/her peers for scientific guidance may differentially contribute to the commercialization of technology discovered in his/her university lab. Indeed, Stuart and Ding (2006) document that it is precisely the star scientists who were the first to cast aside Merton's (1968) norms of scientific behavior and legitimize entrepreneurial activity by academic faculty.[2]

A renowned faculty inventor (i.e., a star) discussed some of his early contributions to the firm he founded: 'I was at Berkeley and started my first firm in 1982. The ideas for the firm were built originally out of my work at the university . . . The firm (with my intense involvement) ended up re-doing much of the work done at Berkeley to make it work in the market. It was a big success . . . I'm still the chief technology advisor for the firm, spending a lot of my personal time with them even now many years after the founding.'

Besides human capital, star scientists also bring substantial social capital to their ventures. In particular, Murray (2004) has documented how scientists leverage their social capital, accrued through years of participating in the academic community by publishing and refereeing papers, attending and participating in conferences, writing and evaluating grant applications, and so on, into social capital for their new ventures. Benefits to social capital are well established in the entrepreneurship literature (Stuart, Hoang, and Hybels, 1999). They include, among others, access to resources, such as funding and key employees, as well as information pertaining to busi-

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[2] Merton described four norms of science: universalism, communism, disinterestedness, and organized skepticism.

ness opportunities, endorsements by other higher status partners in the social network, and a faster IPO at higher valuations.

We argue, moreover, that the human and social capital effects are even more pronounced for star scientists. Star scientists are considered to embody more valuable human capital (Zucker *et al.*, 2002) and tend to have higher social capital due preferential attachment and the Matthew effect (Higgins, Stephan, and Thursby, 2011; Merton, 1968). In addition, one of the more striking differences between average and star faculty founders is the fact that star scientists have the ability to signal the (unobserved) quality of the new venture to external actors. While the average faculty has private information about the project to be commercialized, he/she will be disadvantaged in signaling the underlying quality to external actors. As demonstrated in the seminal work by Spence (1974), being able to send a credible signal is especially important when the outcome of an endeavor is uncertain. The more uncertain the endeavor, the more important a credible signal becomes. Commercializing faculty inventions are clearly uncertain ventures (Agrawal, 2006).

Achieving the distinction of a star scientist is a credible signal because it obeys the two criteria that Spence (1974) put forth: first, it is within the power of some actors to alter the signal and, second, obtaining the signal is inversely related to the underlying (and unobserved) productive capability of the actor. Supporting the notion that star scientists act as powerful signals in attracting resources and, thus, affecting positive organizational outcomes, Higgins *et al.* (2011) show that new biotechnology firms with star scientists achieve higher IPO valuations.

Taken together, we suggest that a star scientists as faculty founder brings differential human and social capital to the start-up, above and beyond what an average faculty founder can accomplish. Additionally, a star faculty founder is able to signal and endorse the quality of the new venture to external resource providers.

Hypothesis 2: An NTBF founded by a star faculty inventor will have a higher probability of a liquidity event over and above those of an NTBF founded by an average faculty inventor.

Contingency effects

Going beyond direct effects of (star) faculty founders on the likelihood that a new technology

venture will have a liquidity event, we suggest that there are also nuanced contingency effects at work. Sorenson and Stuart (2001) show that the likelihood of a venture capitalist to invest in a new technology venture declines sharply with geographic distance. Simply put, venture capitalists like to invest close to home (e.g., no more than one hour driving distance is often quoted as rule of thumb in the VC industry) in order to better monitor the new venture and to provide advice and so on. The benefits of geographic proximity are particularly salient for new technology start-ups, because venture capitalists not only provide much needed capital and strategic guidance (generally through a seat on the company's board), but often actively recruit new employees (especially experienced executives), legal counsel, suppliers, and customers. Access to localized VC funding was found to be a critical predictor of innovation differentials in geographic clusters in the medical device industry (Rothaermel and Ku, 2008).

In the United States, moreover, venture capital firms are densely clustered in three metropolitan areas: San Francisco, Boston, and New York (Chen *et al.*, 2010). This implies that there are distinct VC-dense and VC-sparse areas. Combining the finding that VC firms are densely clustered in few geographic areas with the empirical fact that VCs prefer to invest locally, new technology ventures not located in a VC-dense area are clearly disadvantaged in obtaining venture capital and, thus, less likely to go IPO (Black and Gilson, 1998). Since much of the knowledge in nascent entrepreneurship tends to be tacit in nature (Agarwal *et al.*, 2010), these types of knowledge exchanges are best done face-to-face. Due to a star faculty's superior signaling quality of the new venture's upside potential (Spence, 1974), we suggest that a star scientist turned faculty founder is able to overcome such a liability of geographic distance to venture capital.

Hypothesis 3: In venture capital-sparse geographies, a star faculty founder will be able to overcome a liability of geographic distance to venture capital and, thus, increase the NTBF's probability of a liquidity event.

Since status benefits can spillover from one actor to another in the web of commercial exchanges (Podolny, 1993), it is likely that faculty benefit from the intangible halo effect of being affiliated with a leading research university. In line with this conjecture, Sine, Shane, and DiGregorio (2003) found that

a university's prestige significantly increased the institution's rate of technology licensing. Top universities attract better faculty and students and spend more on basic research and cutting-edge laboratories equipped with expensive instruments, thus reinforcing the status quo. Being surrounded by a high-quality group of productive scholars has positive performance spillover effects of individual productivity. For example, prior work demonstrates that the group effect can be a stronger predictor of individual productivity than individual-level factors, given a minimum threshold (Perrow, 1995).

Although it is the star faculty that are most likely to engage in commercializing science (Stuart and Ding, 2006), their signaling effect is likely to depend somewhat on the quality of their home department. At some top universities, stars come a dime a dozen, while at rank-and-file universities, star scientists are a rare occurrence. Thus, if a star scientist is affiliated with a lower-ranked university (and some in our sample are), we expect his/her signaling ability to be even stronger because it is not diluted by the halo effect of being part of an elite university. In addition, the local and cosmopolitan networks unearthed by Murray (2004) that an NTBF can draw upon are less likely to show network overlap for a scientist affiliated with a lower-ranked university. In this case, the local network of collaboration is likely to be distinct from the star's cosmopolitan network at scientific conferences and prestigious appointments (e.g., NIH). In contrast, for stars holding appointments at the very top research universities, some of the same researchers (i.e., colleagues) are likely to make up the star's local as well as cosmopolitan networks. Thus, being affiliated with a lower-ranked university allows the star scientist to leverage distinct, nonredundant networks. Some preliminary support of this idea is provided by Hansen, Podolny, and Pfeffer (2001), who found that teams with strong external ties that were nonredundant completed their projects faster.

Taken together, due to their stronger signaling quality and the ability to tap into nonredundant networks, we argue that star faculty founders are able to overcome the disadvantage of not being affiliated with one of the top research universities.

Hypothesis 4: A star faculty founder will be able to overcome the disadvantage of not being affiliated with one of the top research universities and, thus, increase the NTBF's probability of a liquidity event.

METHODOLOGY

Sample

To test our hypotheses, we created a sample of new technology ventures working on commercializing university-related research that may have academic faculty inventors involved as founders. We relied on a novel use of some existing data that has previously not been exploited in the entrepreneurship literature: patent assignments.[3] By merging together a list of active science and engineering faculty with U.S. patent data, we created a set of patents in university-relevant technologies where academic faculty were listed as inventors (Thursby, Fuller, and Thursby, 2009). In a second step, we created a group of new technology ventures attempting to commercialize these inventions in the marketplace.

In particular, we obtained a list of 34,202 faculty members in science and engineering departments at 87 Research 1 Universities in the U.S.[4] The initial faculty data were obtained from the National Research Council (NRC) for the year 1993 (Goldberger, Maher, and Flatteau, 1995). We then checked the faculty names against U.S. patent inventor names. We gathered patent data from the National Bureau of Economic Research (NBER) (Hall, Jaffe, and Trajtenberg, 2001). We started with patents that had application dates from 1993, but also took samples from patents granted in 1997, 1999, and 2004 (after eliminating duplicates). The process entailed a detailed search algorithm using first, middle and last names and then a geographic triangulation for any matches still in doubt.[5] We checked faculty names manually against the annual National Faculty directories for the years from 1995 through 2002 to verify a continuing affiliation with the university. This process yielded a sample of 5,818 patents, all with an active U.S. faculty member listed as an inventor.

In addition, these patents with a university faculty listed as an inventor also contained 1,050 assignee firms. We use this linkage to establish a sampling frame of firms that are working in university-related technologies. To track technology ventures forward

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[3] We thank Bronwyn Hall for helping us with this insight.
[4] The National Research Council uses the Carnegie classification system of universities. This implies that the 87 universities in this faculty list are all PhD-granting science and engineering universities with high levels of research activity.
[5] A more detailed description of the sample and the academic faculty-patent inventor matching process is available upon request.

rather than to sample on surviving incumbent firms, we established 1980 as the earliest founding date we would count as a potential start-up firm in order to coincide with the growth in university entrepreneurship following the Bayh-Dole Act (Rothaermel *et al.*, 2007). Using state-level incorporation data, we sorted based on founding dates and created a sample of 711 'start-up candidates.'

Next, to separate 'lifestyle' start-ups and Schedule C companies created for tax write-off advantages from 'real' technology ventures, we conditioned the sample on firms that had asked for and received VC funding.[6] This is because firms that are trying to commercialize new technology tend to require more funding than organically available, as emphasized in the literature (Katila, Rosenberger, and Eisenhardt, 2008) and validated in our own field work. We obtained these data from *Venture One* and *Venture Expert*, well-established sources in prior research (Dushnitsky and Lenox, 2005; Dushnitsky and Shapira, 2010; Gompers, 1995; Kaplan and Stromberg, 2003).

Of the initial 711 firms in the sampling frame based on both VC data sets, we were able to obtain at least some data on 296 technology start-ups.[7] We followed each firm forward from January 1, 1980 to December 31, 2005 to determine its exact founding date as well as the exit status (private, public, acquired, or failed) and date. Based on detailed triangulation of multiple sources (SEC filings, Lexis-Nexis, state legal records, etc.), we were able to obtained a fine-grained and reliable data set of 238 new technology ventures. The firms in our final sample were founded from 1980 to 2003. More than 70 percent of the firms started from 1987 to 2000. The peak years for firms to be founded were 1989 (21 firms, or 8.8 percent), 1992 (18, 7.6 percent), and 1998 (17, 7.1 percent).

The sample comprises 238 university research-related technology ventures hailing from 65 U.S. universities. Of these, 49 percent (117 firms) have active science or engineering faculty members as firm founders. MIT has 26 firms in the sample, of which 14 (53.8 percent) have faculty members founders. Stanford has the highest number of firms with faculty founders (at 16, or 69.6 percent of their 23 firms). UC-Berkeley is third overall and tied with MIT at 14 faculty-founded firms.[8] The sample also includes a number of different industries, with biotech (42 percent) and electronics (17 percent) being the largest sectors.

Taken together, this sample resonates with recent studies of multiple technologies across several industries rather than the dominant prior literature using a single-industry perspective (Woolley, 2010). It is also noteworthy that finding statistically significant results that hold across different industrial sectors represents a more conservative approach than obtaining significant results based on a single-industry sample (Hitt, Gimeno, and Hoskisson, 1998) and, thus, makes our hypotheses more generalizable.

Data

Dependent variables

We evaluated university-related technology ventures along one of four possible outcomes (*IPO*, *Acquired*, *Private*, and *Failure*). A sample firm is at risk from birth to first event. Following prior research on university start-ups, we define liquidity as an initial public offering (Nerkar and Shane, 2003).[9]

Independent variables

The key variable of interest is not only whether the founder of the firm was a faculty member (*1 = Faculty Founder*) to test H1, but whether the faculty founder is a 'star scientist' (*1 = Star Faculty Founder*) to test H2. We proxied the presence of a faculty founder by his/her inclusion in the top one half of one percent of cited scholars in his/her field based on the data provided by Thomson 'ISI Highly Cited'[10] (Zucker and Darby, 2009).

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[6] We appreciate the fact that this sampling includes only firms that actually *receive* VC funding, rather than all firms that *applied* for VC funding. While this likely accounts for some survivor bias, it should be noted that *all* the firms in the sample share this same condition. Therefore, as we later stratify by which firms have a faculty inventor founder and which do not, we are not biasing our results in terms of key theoretical variables of interest. Indeed, since all firms received VC funding, finding significance for any faculty inventor effect above and beyond might be an even a more conservative approach.

[7] We performed thorough cross-checks of the key data elements to enhance the reliability of the data for these early-stage firms. For example, 121 firms were found in both Thomson's Venture Expert and Dow Jones's Venture One databases (the balance were found in one or the other data set).

[8] The complete data detailing the number of all 238 NTFBs per university and the percent of faculty founders is available upon request.

[9] IPOs are considered a success, at least by the VCs and other major investors. Acquisitions are much harder to define as a success or a 'fire sale.' We adopted this most conservative definition for our primary analysis.

[10] 'ISIHighlyCited highlights the top 250 preeminent individual researchers in each of 21 subject categories who have demonstrated great influence in their field as measured by citations to their work' (www.isihighlycited.com).

Contingency effects

We introduced two contingency effects in our hypotheses development: VC density and elite university research funding levels. In recent work, Chen *et al*. (2010) found that the most VC-dense areas in the U.S. are the Boston, San Francisco, and New York City metropolitan statistical areas (MSAs). We included an indicator variable set to 1 if the NTBF was located in one of these three MSAs (*VC Dense Cities*). Looking at the 1985 to 2005 time period, Chen *et al*. (2010) found that these areas consistently were home to 46 to 52 percent of all VC offices in the U.S. Although many subjective rankings of university quality are available (such as the Gourman Report), we used the amount of NSF funding a research university received as the indicator of research quality (*Top University R&D*).[11] This measure is set to 1 if the faculty member's university is among the 10 largest receiving NSF funding and 0 otherwise.

Control variables

We control for age of the firm at the time of first funding (*Time to VC Funds*). This allows us to separate out individual firm financial strength from other factors of success.[12] To account for the general financial environment, we include three variables covering both firm founding and the liquidity event horizon. First, we use the NASDAQ (inflation adjusted) average annual close value in the year of the liquidity event of the firm (*NASDAQ Event Year*). During our study time window, NASDAQ was the most common listing exchange for NTBFs upon a successful IPO. This variable helps control for overall economic conditions in the high-technology industry. Such conditions are known to have an impact on the alternatives firms have for IPOs, acquisitions, or further VC funding (Gompers and Xuan, 2006).

A second economic variable we include at the liquidity event time is a measure of the state of the IPO markets (*Hot IPO*). It is well established in

the finance literature that IPOs in particular are subject to 'hot' and 'cold' markets (e.g., Ibbotson and Jaffe, 1975; Ritter, 1984). We followed Helwege and Liang (2004) in using a three-month moving average of IPO issues. We further extended this measure into 2005 by using a similarly defined 'hot' window period as did Yung *et al*. (2008).

Just as 'hot' IPO markets influence when firms may initiate IPOs, plentiful VC spending is likely to create cycles in the process of forming new ventures (Lerner, Shane, and Tsai, 2003). We, thus, assess the availability of VC funding in the year of firm founding using the total annual early-stage capital spent on start-up firms by private U.S. VCs (*U.S. VC Seed Funds*). These data were collected by the National Science Foundation as part of their science and engineering indicators.

Additionally, we controlled for size of VC firms investing in the NTBF (*Top 10 VC Firm Invested*). Prior research has shown size is a proxy for quality in both VCs and underwriters (Megginson and Weiss, 1991; Higgins *et al*., 2011). Therefore, we added an indicator variable (set to 1), if one of the 10 largest U.S. venture capital funds invested in any round of funding. The largest VCs were selected by total dollars invested, as reported by *Forbes Magazine* with data from Venture Economics.[13] The investment of corporate venture capital has also been shown to have a signal effect on the marketplace (Benson and Ziedonis, 2010; Wadhwa and Kotha, 2006). We add an indicator variable (set to 1) if an incumbent firm has invested in the firm (*Corporate VC Invested*).[14]

We use firm-level patent counts to control for intellectual property across firms (*Patent Stock*). We searched each firm for all patents applied for or issued from the date of founding to the first exit event. We took the natural log of this count variable to improve the normality of the distribution given a high degree of skewness in patent counts. We also included a department quality variable collected by the National Research Council (*Faculty Department*

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[11] The 10 universities with the highest level of NSF funding in 1993 were Cornell, Johns Hopkins, Michigan, Minnesota, MIT, Stanford, UC San Diego, UC San Francisco, Washington, and Wisconsin. As a robustness check, we also used the top 10 NSF-funded universities in 1999 and got substantially the same results.

[12] We also created a variable for the amount of funding raised in the first round (since we conditioned on VC funding, all our firms have at least one round of funding); however, this variable was not significant in any of our models.

[13] These VC firms are: Accel Partners, EM Warburg, Kleiner Perkins Caufield & Byers, Menlo Ventures, New Enterprises Associates, Oak Investment, Softbank VC, Spectrum Equity, Summit Partners, TA Associates, and Technology Crossover.

[14] We considered gathering angel-invested funds and other non-VC dollars but our interviews indicated even for firms that may have gotten some 'friends and family funding,' VC dollars were still needed and provided a much larger base of financial support. In addition, some prior work with fine-grained funding data indicates the magnitude of VC funding is much higher than angel or friends investing (Rothaermel and Thursby, 2005).

Quality). We linked this variable to the faculty inventor listed on the patent assigned to the firm.[15] Finally, we used a dummy variable to indicate whether the underlying technology was based on biotechnology (*Biotech Industry*). Biotechnology is a fundamental technology platform affecting many different industrial sectors (Galambos and Sturchio, 1998). As a consequence, biotechnology has been the most prevalent technology emanating from research universities to date and, thus, is also the one industry setting that is most often used in prior studies (e.g., Murray, 2004; Rothaermel and Deeds, 2004; Stuart, Ozdemir, and Ding, 2007; Zucker *et al.*, 1998).

RESULTS

Table 1 presents descriptive statistics and a bivariate correlation matrix. We evaluated the status of university research-related technology ventures until the end of our study period (December 31, 2005) using bivariate logistic regression on exit events as IPOs. The coefficients reported are odds ratios.[16]

Table 2 presents the results to test Hypotheses 1 and 2. In Models 2.1 to 2.4 in Table 2, the dependent variable is the likelihood of the new technology venture achieving an initial public offering. Model 2.1 presents the baseline model, including the control variables only. In Model 2.2, we test Hypothesis 1, where we posit that a new tech venture founded by a faculty inventor will have a higher probability of liquidity events over an NTBF formed to commercialize a faculty invention, but without the faculty inventor as founder. We find that the odds ratios for all faculty founders are slightly greater than 1 and statistically significant (odds ratio = 1.01, $p < 0.05$). This result provides support for Hypothesis 1.

In Hypothesis 2, we posit that an NTBF founded by a *star* faculty inventor will have a higher prob-

[15] We use the 1993 NRC survey because that is the year of our original starting point for the faculty list in the sample. University rankings exhibit significant inertia over time, as the same group of universities show up as the dominant research institutions.

[16] An odds ratio of greater (smaller) than 1 indicates an increased (reduced) likelihood that the focal event will occur. We standardized the independent variables prior to entering them into the models (Cohen *et al.*, 2003). Without this transformation, the variety of scales and some data sparseness results in quite large effect sizes of the coefficients. Standardization does not change the general interpretation of the odds ratios presented nor the significance level for the items in the models.

Table 1. Descriptive statistics and correlation matrix

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13
1 Exit status	1.79	1.28													
2 Time to VC funds	2.31	3.38	-0.32												
3 NASDAQ event year	0.97	0.45	-0.21	0.08											
4 Hot IPO	0.42	0.50	0.12	0.26	-0.15										
5 U.S. VC seed funds	2.67	3.66	-0.45	-0.10	0.13	-0.33									
6 Top 10 VC firm invested	0.21	0.41	0.27	-0.21	-0.05	-0.02	-0.07								
7 Corporate VC invested	0.48	0.50	0.20	-0.18	0.19	-0.08	-0.05	0.11							
8 Patent stock	2.37	1.17	0.01	0.12	0.20	0.06	-0.05	0.19	0.11						
9 Faculty department quality	4.04	0.71	0.00	-0.05	0.10	-0.06	0.05	0.13	0.15	0.03					
10 Top university R&D	0.36	0.48	0.02	-0.01	0.07	-0.06	-0.03	0.08	0.15	0.12	0.40				
11 VC-dense cities	0.52	0.50	0.07	-0.17	0.04	-0.02	0.00	0.16	0.19	0.06	0.33	0.20			
12 Biotech industry	0.41	0.49	0.31	-0.13	-0.02	0.13	-0.19	0.00	0.10	-0.06	-0.04	-0.02	-0.08		
13 Faculty inventor founder	0.48	0.50	0.03	-0.12	0.10	-0.08	0.15	0.05	0.10	-0.05	0.32	0.15	0.11	-0.02	
14 Star faculty inventor founder	0.11	0.31	0.02	-0.09	-0.01	-0.07	0.14	0.17	0.06	0.03	0.15	0.05	0.06	0.06	0.37

n = 238; $r > 0.13$ are significant at $p < 0.05$

Table 2. Predicting the likelihood of initial public offerings

Standardized variables	BIVARIATE LOGIT REGRESSION			
	PUBLIC (1) VS. PRIVATE (0)			
	MODEL 2.1	**MODEL 2.2**	**MODEL 2.3**	**MODEL 2.4**
	ODDS RATIO	ODDS RATIO	ODDS RATIO	ODDS RATIO
Time to VC funds	0.29***	0.28***	0.25***	0.25***
NASDAQ event year	0.53**	0.45**	0.58*	0.49**
Hot IPO	0.50*	0.42**	0.45**	0.40**
U.S. VC seed funds	0.92***	0.91***	0.91***	0.89***
Top 10 VC firm invested	3.04***	3.32***	2.93***	3.27***
Corporate VC invested	1.78*	1.88*	1.79*	1.91*
Patent stock	1.66*	1.85*	1.64	1.8*
Faculty department quality	0.74	0.60	0.64	0.54*
Biotech industry	2.64***	2.43**	2.69**	2.47**
Faculty inventor founder		1.01*		1.01
Faculty inventor founder*STAR			2.94**	2.56**
Pseudo R^2 =	0.62	0.65	0.65	0.67
Number obs =	177	177	177	177

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$ (one tail)

ability of a liquidity event versus an NTBF founded by an average faculty inventor. In Model 2.3, we find that star faculty founders are statistically significantly correlated with the likelihood of their venture achieving an IPO (odds ratio = 2.94, $p < 0.01$). Moreover, in Model 2.4, we test the effect of star faculty founders on the likelihood of achieving an IPO while explicitly controlling for average faculty founders. The results remain robust and, thus, indicate that a star faculty founder is statistically significantly correlated with the likelihood of achieving an IPO (odds ratio = 2.56, $p < 0.01$), while the average faculty founder is no longer significant. These results provide support for Hypothesis 2.[17]

[17] To test the robustness of these findings, we added 'good acquisitions' to the IPOs to create a more broadly defined variable of success, increasing the sample to 214 firms. We added all acquisitions (good ones and fire sales) to the dependent variable and also failures to the default count, thus leveraging the full sample of 238 firms. Although some of the control variables remain significant, the key independent variable of star faculty founder does not reach statistical significance. In light of the larger sample but the much lower explained variances in terms (see large drop in pseudo R2), we suggest that these findings are further evidence that IPOs and acquisition are fundamentally different liquidity events, especially when considering such new technology ventures. In particular, IPO tends to be an unambiguous success indicator, with higher valuations than acquisitions (Ritter and Welch, 2002; Shane and Stuart, 2002).

In Table 3, we present the results for the two contingency relationships advanced. In Hypothesis 3, we argue that a star faculty founder will be able to overcome a liability of geographic distance to venture capital and, thus, increase the NTBF's probability of a liquidity event. To test this contingency effect, we split the sample along the geographic demarcation of whether the new tech venture is located in a VC-dense area (i.e., Boston, New York, or San Francisco) or not. Please note that the sample splits nicely: roughly 50 percent in each category. When comparing Models 3.2 and 3.4, we see that a star does *not* have a significant effect above and beyond an average faculty founder when the firm is located in VC-*dense* areas where venture capital is abundant. In contrast, in VC-*sparse* areas, a star faculty founder is statistically significant in predicting the likelihood that the new venture will go public ($p < 0.001$, Model 3.2). As predicted, a star scientist is able to overcome the liability of geographic distance to venture capital and, thus, increase the NTBF's probability of an IPO.

In our second contingency hypothesis (H4), we posit that a star faculty founder is able to overcome the disadvantage of not being affiliated with one of the top research universities and, thus, increase the NTBF's probability of a liquidity event. The sample is divided into two categories: the top 10 universities

Table 3. Predicting the likelihood of initial public offering: contingency effects

Standardized variables	MODEL 3.1 Odds ratio Sparse VC areas	MODEL 3.2 Odds ratio Sparse VC areas	MODEL 3.3 Odds ratio Dense VC cities†	MODEL 3.4 Odds ratio Dense VC cities†	MODEL 3.5 Odds ratio TOP 10 NSF univ	MODEL 3.6 Odds ratio TOP 10 NSF univ	MODEL 3.7 Odds ratio Other univ	MODEL 3.8 Odds ratio Other univ
Time to VC funds	0.13*	0.03***	0.60	0.57	0.13*	0.17*	0.34**	0.33*
NASDAQ event year	0.42*	0.64	0.34**	0.39**	0.04*	0.04**	0.37**	0.38**
Hot IPO	0.55	0.31	0.23*	0.21**	1.14	1.09	0.28*	0.28*
U.S. VC seed funds	0.88**	0.84**	0.91***	0.89***	0.79*	0.79**	0.88***	0.88***
Top 10 VC firm invested					4.78**	4.92**	4.13**	3.96**
Corporate VC invested	2.64	1.99	1.82	2.15	61	80.4	1.14	1.12
Patent stock	1.13	1.74	3.81**	3.98**	2.92*	2.39	1.59	1.58
Faculty department quality	0.98	0.60	0.25*	0.22*				
Biotech industry	2.77**	11.2***	2.44*	2.23**	2.72*	2.73*	2.49*	2.49*
Faculty inventor founder	1.00	0.99	1.02**	1.02***	1.05**	1.05**	1.00	1.00
Faculty inventor founder*STAR		12.62***		2.39		1.52		2.31*
Pseudo R²	0.74	0.79	0.56	0.58	0.77	0.77	0.69	0.69
N	83	83	94	94	64	64	113	113

†Boston, New York City, and San Francisco
*p < 0.05; **p < 0.01; ***p < 0.001 (one tail)

based on receiving NSF funding and the remaining universities in the sample. As shown in the results presented in Model 3.8, we find support for Hypothesis 3. Although a star faculty member does *not* add a significant incremental effect above and beyond that of an average faculty founder when affiliated with a top research university (Model 3.6), the star faculty founder does have a significant effect on the likelihood of an IPO if affiliated with lower-ranked research university ($p < 0.05$, Model 3.8).

Robustness checks

We conducted a number of robustness checks. Besides those already noted, we ran a probit regression on the sample to delineate any significant differences between firms *with* a faculty inventor founder and those *without*. All characteristics tested no significant differences between the two groups, except the department quality variable. We were careful to include controls for quality in all of our hypothesis testing. We also evaluated a more purely reputational variable, which was election into the National Academies (either science or engineering). This factor, however, was not significant in our models. This may indicate that actual publication citations are a good measure of scholars who have valuable information embodied in their research and, thus, a valid proxy for their ability. This could help differentiate actual quality measures from perceived quality measures.

We also accounted for a possible right-hand side truncation effect, because newer firms have less time to experience liquidity events. As a robustness check, we dropped all firms founded after 1997, since the average time to IPO in our data and across industries broadly is seven years (Loughran and Ritter, 2004). All other results noted also remain the same with this smaller sample (n = 132).

DISCUSSION

Faculty entrepreneurship is becoming an increasingly common phenomenon, making significant contributions to job creation and economic growth (Kauffman, 2010). Our research goes to the heart of faculty entrepreneurship. Specifically, we study the differential outcomes of new technology ventures with at least one science or engineering faculty member on the founding team, compared with similar start-ups without faculty founders. We leverage underutilized data in patent assignments to create a broad sample of new technology ventures. The sample of firms covers a wide variety of industries, and all firms attempt to commercialize university-related research. Rather than focusing on just one or a few elite universities, the 238 new technology ventures in our sample come from 65 U.S. universities.

In contrast to prior research, we demonstrate that faculty inventors exert *both* selection as well as treatment effects which, in turn, differentially affect the likelihood of success for the new tech ventures. In particular, new ventures with faculty founders have a greater likelihood of achieving an IPO than ventures that were founded based on faculty research but without the benefits of having a faculty founder. Further, in one of the few works of which we are aware, we show that star inventors are differentially important versus typical faculty founders. Through testing the effects of average versus star faculty members, we were able to make some progress in the thorny issue of how to tease apart a selection versus treatment effect when studying the impact of faculty founders on early-stage venture performance. Our research strategy was to unearth heterogeneity among faculty founders. All faculty founders have the benefit of the private information (and all have acted upon it), but not all faculty are equally productive and talented, thus there exists large heterogeneity among faculty founders (Hess and Rothaermel, 2012).

While faculty founders are positively correlated with the likelihood of university-technology ventures achieving an IPO, the effect is even stronger if the founder is a star scientist. When inserting both 'average faculty founder' and 'star faculty founder' in the regression analysis, the average faculty founder is no longer significant, while the star faculty founder remains significant. This latter result resonates with the recent findings in Higgins *et al.* (2011) when studying the effect of Nobel laureates on a firm's scientific advisory board and the subsequent valuations of these new biotechnology firms at IPO. Combining this important heterogeneity with the a multi-industry sample across a large number of universities allowed us to identify specific conditions when stars shine.

An additional novel theoretical contribution of this research is to specify critical contingencies when star scientists turned entrepreneurs are especially important to the performance of new technol-

ogy ventures. We find that stars are able to overcome important handicaps that would seem to hinder a new venture's initial public offering. In particular, we find that star faculty founders are especially valuable to new ventures when the start-up is located in a VC-sparse area and the star's faculty appointment is not at an esteemed research university. Specifying important contingencies when star faculty founders are particularly critical to new venture success is important because it provides a deeper understanding of *how* star scientists influence the performance of the firms they create. These findings, therefore, provide important boundary conditions delineating the relevance of star knowledge workers within the newly emerging research stream on microfoundations of strategy and entrepreneurship (Bingham and Eisenhardt, 2008; Bingham *et al.*, 2007; Felin and Hesterly, 2007; Rothaermel and Hess, 2007).

Taking the star's ability to overcome geographic distance to venture capital and its ability to shine more brightly at lower-ranked universities, it appears that these findings are driven to a large extent by the star's ability to send a credible signal about the unobserved quality of the new venture to external actors (Spence, 1974). Although, VCs have a strong preference to invest locally (Sorenson and Stuart, 2001), they are willing to overcome the liability of geographic distance if the founder of the firm is a well-recognized star scientist. In addition, the signal the star sends is less diluted—and, thus, more clearly visible—if the star is affiliated with a lower-ranked university. This star does shine more brightly, but also has the ability to tap into important nonredundant networks and, thus, increase the social capital with which the new technology is endowed.

It is likely that there is faculty consulting and involvement by academics in the nonfaculty-founded firms. This, however, makes our results all the more striking. We have identified that when an inventor actually creates a new ventures, this has a substantial impact on increasing the chances of a liquidity event over other similar firms. We submit that this speaks to the determination of those who choose to push forward with commercializing university technology themselves (inventors turned into entrepreneurs) versus those who will answer questions from others (consultants) about the often messy issues in bringing new technologies to market.

Our decision to focus on firms that have been successful at gaining some level of venture capital funding may actually suppress the importance of academic inventors, particularly those who are

founders of the firm. Venture capital contracts are often written to give the VC authority to reorganize the firm and even replace founders and managers as appropriate (Kaplan and Stromberg, 2003; Pollock, Fund, and Baker, 2009). Other scholars have suggested that VCs invest in firms that are not overly dependent on any specific person (Zingales, 2000).

CONCLUSION

In conclusion, we provide three major contributions in this research. First, we identify that faculty inventors turned firm founders do matter to the outcomes of new technology ventures. Their selection of their most promising projects to start a firm increases the likelihood that the firm will go public. This effect is robust to several variants of financial and intellectual firm-level controls. Second, *star* faculty inventor founders have incrementally *more impact* on the likelihood of the firm having an IPO. Faculty matter and highly productive and impactful faculty matter more in the outcomes of firms. To clarify this treatment in more detail, we identify specific situations in which stars shine. In terms of research methodology, we complement our quantitative findings on this treatment effect with qualitative field work to provide some insights into the *type* of treatment these star inventors provide. Finally, we extend research on faculty entrepreneurship beyond the boundaries of only the most esteemed universities and single-industry studies generally conducted in the biotechnology sector.

The field work we conducted also points to some major reasons for these results. It was clear across the board for the faculty inventor founders interviewed that they each had a high level of passion and commitment for the success of their firms. This passion was starkly absent when they were asked about consulting they engaged in either prior or subsequent to founding their firm. Each inventor could also identify specific technical areas where their years of trial-and-error research and experimentation were instrumental in guiding the firm away from 'sink holes' of development effort. Finally, several of our interviews brought out the somewhat limited role of codified knowledge in university patents when attempting to commercialize university-related research. While qualitative in nature, it was surprising to us that the range of useful information for commercialization in a university patent was esti-

mated to be only *20 to 50* percent of what is needed to successfully commercialize the invention. This once more highlights the importance of direct inventor involvement in successful commercialization, ideally not as consultants but as entrepreneurs; diving in to start firms and get their ideas into the marketplace as successful products and services.

ACKNOWLEDGEMENTS

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