Venture Capital
Vol. 11, No. 2, April 2009, 133–162

Why do some US universities generate more venture-backed academic entrepreneurs than others?

Junfu Zhang*

Department of Economics, Clark University, Worcester, MA, USA

(*Accepted 18 August 2008*)

In this study, I identify academic entrepreneurs using biographical information on start-up founders contained in a comprehensive venture capital database. Multivariate analyses are conducted to investigate why some US universities generate more venture-backed academic entrepreneurs than others. I find that national academy membership and total faculty awards are the most significant variables in explaining the number of venture-backed entrepreneurs from a university. In contrast, the abundance of venture capital near the university has no significant effect, which is surprising given that this study focuses exclusively on venture-backed entrepreneurs.

Keywords: academic entrepreneur; university spin-off; venture capital

1. Introduction

US universities such as Stanford and MIT played a crucial role in the development of regional high-tech economies, partly through generating academic entrepreneurs and spinning off technology companies (Saxenian 1994; Zhang 2003). Following Stanford and MIT, many universities have taken on a new mission to contribute to local economic development by transferring technologies to the private sector (Etzkowitz 2002). Throughout the world, more and more universities have become engaged in promoting academic entrepreneurship and many of them turn to the experience of MIT and Stanford for inspiration and lessons (Roberts 1991; Roberts and Malone 1996; Shane 2004). It is thus important to understand why universities like MIT and Stanford succeeded in generating entrepreneurs and new businesses.

In this study, I empirically examine why some US universities generate more venture-backed academic entrepreneurs than others. I define academic entrepreneurs as start-up founders who had worked at universities before starting their firms. Their start-ups will be referred to as university spin-offs. The main goal of this study is to inform policymakers and practitioners who want to understand what factors make a university successful in spawning new businesses. By answering this question, this study seeks to contribute to the empirical literature on academic entrepreneurship.

The literature on academic entrepreneurship, although growing steadily, is facing two problems. First, there is no grand theory that can provide a unifying framework for empirical research. As a result, empirical studies in this area are loosely related,

*Email: juzhang@clarku.edu

ISSN 1369-1066 print/ISSN 1464-5343 online

DOI: 10.1080/13691060802525270
http://www.informaworld.com

sometimes only by sharing the same subject of study. Audretsch and Stephan (1996) find that when biotech companies are founded by university-based scientists, their founders tend to be local. Research by Zucker and Darby and co-authors (e.g. Zucker, Darby, and Armstrong 1998; Zucker, Darby, and Brewer 1998) show that 'star scientists' have a significant effect on the timing and location of the formation of biotechnology companies. Shane (2004) provides a comprehensive synthesis of his and related research on different aspects of academic entrepreneurship. He uses data mainly from MIT, one of the most successful research institutions in spawning technology companies. Feldman (1994), by contrast, studies why a top research university such as Johns Hopkins contributes little to the local economy through academic entrepreneurship and knowledge spillovers. Because these studies are loosely related, the empirical knowledge learned from them is highly fragmented.

Second, empirical research on academic entrepreneurship is constrained by limited data availability. Researchers in this area resort to all kinds of data sources. As a result, depending on the data at hand, they often invoke very different definitions of academic entrepreneurship and university spin-offs.[1] Klofsten and Jones-Evans (2000) use a very broad definition of academic entrepreneurship that covers not only new firm formation but also consulting and patent-seeking activities of academics. In Stuart and Ding (2006), an academic entrepreneur may only serve on the scientific advisory board of a start-up.[2] Several studies, largely done by Scott Shane and co-authors, investigate 'university spin-offs' as start-ups exploiting university inventions but not necessarily founded by university employees (e.g. Shane and Stuart 2002; Di Gregorio and Shane 2003; Nerkar and Shane 2003; and O'Shea et al. 2005).[3] Because I focus exclusively on university employees who have founded new firms, these studies, though related to my work, do not examine exactly the same type of academic entrepreneurship.[4]

Also because of the data constraint, researchers in this area often focus on a small number of universities and rely on case studies or small-scale survey data.[5] Lowe and Gonzalez-Brambila (2007) and Toole and Czarnitzki (2007) are perhaps the only studies that use a definition of academic entrepreneurs similar to mine and perform a systematic analysis of relatively large data samples. Lowe and Gonzalez-Brambila identify 150 'faculty entrepreneurs' in 15 academic institutions and investigate whether entrepreneurial activities affect their research productivity. Toole and Czarnitzki identify 337 academic entrepreneurs by matching the National Institute of Health (NIH) researcher database with data from the US Small Business Innovation Research (SBIR) program. They find that firms linked to academic scientists show a better performance in terms of receiving follow-on venture capital investment, completing the SBIR program, and filing patent applications.

In this paper, I employ a comprehensive venture capital database to identify academic entrepreneurs. This database tracks all venture-backed start-ups in the United States and has detailed firm-level information. Most importantly, it contains biographical information about a large number of start-up founders, which makes it possible to detect whether a founder has ever worked for a university. I counted the number of academic entrepreneurs for each of 150 US universities. Additional data on the characteristics of these universities were collected from various sources. I then conducted a series of multivariate analyses to investigate why some US universities generated more venture-backed academic entrepreneurs than others.

The main contribution of this paper is compiling and analyzing a substantially larger data sample of academic entrepreneurs that was previously unavailable. The larger sample permits a richer understanding of the various factors that may explain the number of venture-backed academic entrepreneurs at the university level. Despite this improvement upon existing literature, this study has its limitations. In particular, the sample of academic entrepreneurs is constructed from a database that covers venture-backed academic entrepreneurs only, which perhaps constitute only a small proportion of all academic entrepreneurs.[6] Furthermore, it may not even be a random sample of venture-backed academic entrepreneurs, because start-ups with founder information missing have to be excluded from my analysis. Therefore, the empirical results in this study are subject to potential sample selection biases. Unfortunately, it is impossible to correct for such potential biases using standard statistical techniques because little is known about the factors that may have determined the sample selection. For these reasons, the analysis in this study is exploratory in nature and the empirical results are mostly suggestive rather than conclusive. Nonetheless, I hope that this study will help researchers as well as practitioners better understand the phenomenon of academic entrepreneurship and stimulate further research along this line.

The rest of the paper is organized as follows: Section 2 develops testable hypotheses based on existing literature. Section 3 describes the data sources that are used to construct the variables for the empirical study. Section 4 presents empirical results on the determinants of venture-backed academic entrepreneurship at the university level. Section 5 offers some concluding remarks.

2. Theory and hypotheses

In this section, I develop a series of testable hypotheses to explain the variation in the number of academic entrepreneurs at the university level. Throughout this section, I discuss academic entrepreneurship within the conceptual framework that Shane and Venkataraman (2000) proposed for studying entrepreneurship in general.

Shane and Venkataraman (2000) consider entrepreneurship as a process that involves discovering and exploiting profitable opportunities. A profitable opportunity may take various forms, including the knowledge of a new product, service, raw material, or a new way to organize production or deliver services. Note that all of these opportunities may be discovered in academic research. Consider a hypothetical example. While doing academic research, a biologist found that a particular type of protein stimulates the production of red blood cells in human body. Before long, the researcher and others who are aware of this protein would recognize a profitable opportunity: one could produce and sell the protein to be used for treating diseases such as anemia.

Shane and Venkataraman (2000) point out that not all discovered opportunities are exploited. The decision to exploit an opportunity depends on the nature of the opportunity and the individual characteristics of discoverers. For example, an opportunity with a higher expected value is more likely to be exploited. And individuals who have lower opportunity costs or are more optimistic will likely seize profitable opportunities by starting new businesses. Although Shane and Venkataraman did not emphasize it, one would expect that the social and institutional environment also affects an entrepreneur's decision to exploit a profitable opportunity (Aldrich 1990). For example, if a researcher has many colleagues who have become entrepreneurs, he himself is likely to become one when he sees an opportunity (Bercovitz and Feldman 2008). Similarly, if a university has the institutions to support and facilitate entrepreneurship, its faculty members should be more likely to be engaged in firm-founding activities.

Shane and Venkataraman (2000) also discuss the various modes to exploit profitable opportunities. For example, one may choose to exploit an opportunity within an existing organization, sell the opportunity to others, or start a new business. Even if one chooses to start a new business, there are alternative ways to proceed at each stage. For example, one may choose to finance the start-up using personal savings, bank loans, or equity investment from professional capitalists. Naturally, all else being equal, a potential entrepreneur who has easier access to venture capital is more likely to use it to finance a start-up.

This framework for thinking about entrepreneurship helps organize my hypotheses regarding why some universities generate more academic entrepreneurs than others.

2.1. *Quantity of research*

If entrepreneurship is about discovering and exploiting profitable opportunities, as Shane and Venkataraman (2000) suggested, one would expect a positive relationship between the number of academic entrepreneurs from a university and the number of profitable opportunities discovered at the university. However, it is impossible to directly measure the quantity of profitable opportunities. Given that university employees usually discover such opportunities through academic research, the total amount of research at a university should serve as a good proxy. In particular, a university whose faculty has done more research is likely to have produced more commercializable technologies and therefore generate more academic entrepreneurs. There are two ways to measure the volume of research conducted at a university. First, one can examine the amount of input into research. In particular, it seems likely that the more money a university spends on research, the more research results and profitable opportunities its faculty could discover, and therefore the more academic entrepreneurs we expect to see coming out of the university. Second, one can also directly measure research output. Counting the number of academic publications is probably the most commonly used method to measure research output (Lowe and Gonzalez-Brambila 2007; Zucker, Darby, and Armstrong 1998; Zucker, Darby, and Brewer 1998).[7] An alternative way, used in this study, is to measure the 'byproducts' of academic research by counting the number of PhD and postdoctoral students trained at a university. Again, more research output indicates more research findings and profitable opportunities, which in turn would imply more academic entrepreneurs.

> *Hypothesis 1*: Universities that spend more money on research tend to generate more venture-backed academic entrepreneurs.
>
> *Hypothesis 2*: Universities that train a larger number of PhD and postdoctoral students tend to generate more venture-backed academic entrepreneurs.

2.2. *Quality of faculty*

As Shane and Venkataraman (2000) pointed out, not all profitable opportunities are exploited. Research findings with higher market values are more likely to lead to the founding of new businesses, because they are expected to generate more profit than others. Therefore, even if academic researchers at two universities have identified the same number of profitable opportunities, one university may spin off more academic entrepreneurs if its faculty's research findings are generally more valuable on the market. While the expected value of profitable opportunities is not directly measurable, it seems reasonable to use the quality of the faculty as a proxy. More specifically, it is assumed that a more prominent faculty produces more important research findings that have higher commercial values. Therefore, a university with more prominent researchers on its faculty tends to generate more academic entrepreneurs.

In addition to the higher market value of their research findings, there is another reason to believe that a more prominent faculty generates more academic entrepreneurs. Again, as suggested by Shane and Venkataraman (2000), a potential entrepreneur is more likely to exploit a profitable opportunity if the cost of doing so is lower. A prominent researcher may find it easier to create a business because he has more intellectual and social capital to rely on for mobilizing resources (Zucker, Darby, and Brewer 1998). For example, it might be much easier for a prominent researcher to raise venture capital simply because he has better academic credentials. Consider the biotechnology industry that was launched by venture capitalists and professorial entrepreneurs (Kenney 1986). Start-up companies in biotech often spend many years developing a marketable product. When venture capitalists invest in such a start-up, they need to make sure that they can cash out in the future. That is, they wish to be able to sell the company to other investors even before it makes any profit. In such situations, having a prominent scientist on the founding team is a good selling point. In addition, a well-respected scientist may have social connections with powerful people that could help the start-up succeed. For these reasons, venture capitalists may be more willing to invest in start-up founders who are prominent scientists. As a result, one would expect to see more venture-backed academic entrepreneurs from a university with more prominent researchers.

Hypothesis 3: Universities with a high-quality research faculty tend to generate more venture-backed academic entrepreneurs.

2.3. Commercial orientation

Technology transfer and commercialization are relatively new roles for US universities. Although more and more universities are expected to engage in technology transfer and business creation, not all of them have embraced this new role with equal enthusiasm. Universities such as Stanford and MIT have had a long tradition in facilitating and encouraging faculty entrepreneurs, whereas others such as Johns Hopkins are slow in catching up (Etzkowitz 2002; Feldman 1994; Feldman and Desrochers 2003). Universities with a culture and tradition more conducive to academic entrepreneurship are expected to outperform others in terms of business creation. Similarly, universities with policies supporting entrepreneurial activities will likely generate more spin-off companies.[8] Again, a favorable tradition and a supportive environment make it easier, both psychologically and in terms of time and financial costs, for a potential academic entrepreneur to start a business. Therefore, I also postulate the following:

Hypothesis 4: Universities that have been actively engaged in transferring technology to private sectors tend to generate more venture-backed academic entrepreneurs.

2.4. *Accessibility of venture capital*

Start-ups founded by university employees tend to concentrate in high-technology industries, and venture capital has increasingly become an important source of equity investment in such firms (Zucker, Darby, and Brewer 1998). For two reasons, one may expect the availability of venture capital to be related to the observed number of venture-backed academic entrepreneurs from a university. First, potential academic entrepreneurs may face a liquidity constraint (Evans and Jovanovic 1989; Holtz-Eakin, Joulfaian, and Rosen 1994). That is, although many academic researchers may possess commercializable technologies, not all of them have access to the financial resources that are necessary to bring these technologies to market. Other things equal, those who have easier access to capital should be more likely to become entrepreneurs. Using the terminology of Shane and Venkataraman (2000), easier access to venture capital makes it less costly for an academic researcher to exploit a profitable opportunity. Second, even after an academic researcher has decided to start a new firm, there are still alternative ways to finance the new venture. The entrepreneur is likely to raise venture capital if it is more easily accessible relative to other sources of capital. Therefore, the availability of venture capital also makes it the more preferred 'mode' to finance the start-up. For both reasons, one would expect to see more venture-backed entrepreneurs from a university where access to venture capital is easier.

It is well documented that venture capitalists tend to invest in local start-ups (Gompers and Lerner 1999; Sorenson and Stuart 2001). This happens for several reasons. First, venture capitalists tend to rely heavily on their social networks to identify promising business models and entrepreneurs (Tyebjee and Bruno 1984; Shane and Cable 2002). Because social ties are mostly local, they lead to local investment opportunities (Sorenson and Stuart 2001). Second, venture capitalists do not just provide financial capital to an entrepreneur; they also offer advice and guidance to the firm founders, closely monitor their performance, and sometimes sit on the board of directors (Hellmann 2000; Lerner 1995). The physical proximity of the start-up would facilitate these activities. For these reasons, I choose to use the availability of venture capital in the vicinity of the university to measure accessibility to venture capital.

> *Hypothesis 5*: Universities with more venture capital available in the local area tend to generate more venture-backed academic entrepreneurs.

3. Data and variables

VentureOne, a leading venture capital research company based in San Francisco, provided the data on venture-backed start-ups and their founders. Founded in 1987, VentureOne has been continuously tracking equity investment in the United States and abroad. VentureOne tries to identify 'venture-backed companies' by regularly surveying venture capital firms for recent funding activities and scouring various secondary sources such as company press releases and IPO prospectuses.[9] Once a venture-backed company is identified and included in VentureOne's database, VentureOne collects data on the company by regularly interviewing direct contacts at the company and its investors (VentureOne Corporation 2001).

For each venture capital deal, the VentureOne database contains a record of its size, stage of financing, closing date, the venture capital firms involved, and detailed information about the firm that receives the venture capital financing, including its address, founding year, industry, etc. In addition, VentureOne tracks the venture-backed company over time and updates the information about its employment, business status, ownership status, etc. VentureOne claims that it has 'the most comprehensive database on venture backed companies'.[10]

Although VentureOne's database is maintained for commercial purposes, its rich information has attracted many academic researchers. Some recent empirical work, such as Gompers and Lerner (2000), Cochrane (2005), Gompers, Lerner, and Scharfstein (2005), and Zhang (2003, 2007a), has used VentureOne data. Kaplan, Sensoy, and Strömberg (2002) compare VC databases with actual VC financing contracts. They find that the VentureOne data are generally more reliable, more complete, and less biased than the Venture Economics data, the only other major source of US VC data.

The VentureOne dataset used in this study was acquired in late December of 2001. It covers companies that received venture capital investment in the US from the first quarter of 1992 through the fourth quarter of 2001. It includes 11,029 venture-backed firms that completed 22,479 rounds of financing. Among these firms, 83.5% were founded in or after 1990.[11]

VentureOne also provided a separate dataset containing information about venture-backed firm founders.[12] The founder data are incomplete. Founder information is available for 5972 of the 11,029 venture-backed firms.[13] Because many firms are co-founded by more than one individual, I end up with a total of 10,530 individual founders.[14] For each founder, there is a data field containing brief biographical information about the person. It describes the founder's working experience, which, in most cases, not only specifies the companies or institutions a founder worked for, but also includes the positions held.

Based on this biographical information, I constructed a variable to indicate whether a firm founder previously worked for a university or college.[15] If so, values are assigned to a set of variables including the name of the institution, the job position (if indicated), the person's specialty (if identifiable), and the state where the institution is located. For a small group of firm founders who had worked at more than one academic institution, only the latest academic position is counted. In the end, a total of 903 start-up founders are identified as academic entrepreneurs, which constitute 8.6% of the total number of entrepreneurs in the dataset.[16] These academic entrepreneurs founded or co-founded 704 start-ups. For the purpose of this study, I assigned each of the 903 academic entrepreneurs (or 703 start-ups) to a university and calculated *the number of academic entrepreneurs (or spin-offs) from a university*. This variable will be used as the dependent variable in subsequent regression analyses.

It is important to note here that a university's number of venture-backed academic entrepreneurs calculated this way should not be considered as all the venture-backed academic entrepreneurs that ever came from the university. For example, my calculation using the VentureOne data shows that there are 96 academic entrepreneurs from Stanford University. The actual total number of venture-backed entrepreneurs out of Stanford should be substantially higher than this for two reasons: First, the VentureOne data I used only cover firms that received venture capital investment during 1992–2001. If any spin-off company from Stanford were supported by venture capital before 1992, it would not show up in the VentureOne data and thus not be counted. Second, the VentureOne founder data were missing for many firms. Those firms are simply dropped in the process of identifying academic entrepreneurs because it is impossible to determine whether they were founded by academic entrepreneurs.[17] These two layers of sample selection should not bias my empirical analysis below as long as the selection process applies to every university in the same way. Indeed, there is no obvious reason to think that the sample will overrepresent academic entrepreneurs from certain types of universities.

Table 1 is a list of all academic institutions that have at least five academic entrepreneurs captured in the VentureOne data. The number of entrepreneurs and the number of spin-offs they founded are both presented in Table 1. Notice that these two numbers are not the same because an entrepreneur may found more than one firm and a firm may have more than one founder.

Table 1. Top universities by number of VC-backed entrepreneurs and spin-offs.

Institution	No. of entrepreneurs	No. of spin-offs
Stanford University	96	91
Massachusetts Institute of Technology	85	76
Harvard University	58	53
University of California, Berkeley	38	37
Carnegie Mellon University	24	19
University of California, San Francisco	20	17
University of California, San Diego	17	17
Duke University	17	14
University of Washington	16	13
California Institute of Technology	15	15
Columbia University	14	12
University of Michigan	13	13
Yale University	13	12
University of Chicago	13	10
University of Texas, Austin	12	14
Boston University	12	10
New York University	12	10
Georgia Institute of Technology	11	9
University of Southern California	11	8
University of California, Los Angeles	10	11
North Carolina State University	10	10
University of Colorado	10	7
University of Illinois, Urbana-Champaign	10	6
Brown University	9	6
University of Wisconsin, Madison	9	6
University of Minnesota	8	8
Washington University	8	5
Cornell University	7	8
Northwestern University	7	8
Johns Hopkins University	7	6
University of Arizona	7	6
University of California, Santa Barbara	7	6
Princeton University	6	5
University of Pennsylvania	6	5
University of Pittsburgh	6	4
University of California, Davis	5	6
Purdue University	5	5
University of Maryland	5	5
Wake Forest University	5	5
University of New Mexico	5	4
Emory University	5	3

Stanford and MIT overwhelmingly outperform other universities, which is not surprising. The important role of these two academic institutions in the development of Silicon Valley and the Boston region is well documented in the literature (see e.g. Etzkowitz 2002; Gibbons 2000; and Saxenian 1994). While Harvard and UC Berkeley are often considered different from their respective neighbors in terms of their relationships with industry (Etzkowitz 2002; Kenney and Goe 2004), they have also generated many academic entrepreneurs. In fact, they spun off more venture-backed firms than any other institution except Stanford and MIT. One common feature of the institutions listed in Table 1 is that they are all top research universities. No liberal arts college or teaching university makes the list. Even in the whole sample, only a few entrepreneurs are from institutions that specialize in teaching. This seems to suggest that it is the research at these institutions that spurred entrepreneurial activities and attracted venture capital investment.

Table 2 is a list of all the independent variables used in the analysis. To test Hypothesis 5, I used VentureOne data to construct variables that measure the availability of venture capital. I first calculated total local venture capital investment

Table 2. University characteristic variables.

Variable name	Description	Mean	Standard dev.	No. of obs.
NAM99	National academy membership in 1999[a]	19.8	40.1	150
Awards99_01	Total faculty awards during 1999–2001[b]	37.5	37.3	150
Total-Exp91_00	Total research expenditure during 1991–2000	$1.33 billion	1.24	150
SciEng-Exp00	Research expenditure on science and engineering in 2000	$0.13 billion	0.12	150
Doctors98_01	Total doctoral degrees awarded in 1998 and 2000–01	0.68 thousand	0.53	150
Post-Doc98	Number of post-doc appointees in 1998	0.22 thousand	0.35	150
Private	=1 if private and = 0 otherwise	0.35	0.48	150
Local-VC 50	Total venture capital investment within 50 miles during 1992–2001	$2.27 billion	10.7	150
State-VC-Firms	Number of venture capital firms located in the state	49.0	82.2	150
OTT-Age	The age of the Office of Technology Transfer	19.2	12.3	136
Patents 69_00	Total number of patents assigned to the university during 1969–2000[c]	1.69 hundred	2.7	128

Notes: [a]This includes membership in the National Academy of Sciences (NAS), the National Academy of Engineering (NAE), or the Institute of Medicine (IOM). All three academies are private, nonprofit organizations and serve as advisors to the federal government on science, technology, and medicine. Their members are nominated and elected by active members and all get life terms. National academy membership is one of the highest honors that academic faculty can receive.

[b]This refers to awards from 24 prominent grant and fellowship programs in the arts, humanities, science, engineering, and health fields, including Fulbright American Scholars, Guggenheim Fellows, MacArthur Foundation Fellows, NIH MERIT and Outstanding Investigators, National Medal of Science, National Medal of Technology, NSF CAREER awards, etc.

[c]For some multi-campus universities such as the University of California, the University of Texas, and the State University of New York, the patent data are aggregated and not available at the campus level, which creates some missing data at the campus level.

during 1992–2001. For each venture capital deal, VentureOne gives the zip code of the venture-backed firm. I collected the zip codes for all universities through Internet search. These data were merged with the US Census Bureau's ZIP Code Tabulation Area (ZCTA) files[18] to assign latitude–longitude coordinates to the zip codes, which were then used to calculate the distance between any two zip code areas.[19] For each academic institution, I computed the total venture capital investment within 50 miles during 1992–2001 (Local-VC 50). Since it is unclear *a priori* what degree of proximity to venture capital investment will have an effect, I also computed total investment within 25 miles, 75 miles, and 100 miles for sensitivity analysis. Another venture capital variable is the number of venture capital firms located in the university's state (State-VC-Firms). This was constructed based on the directory of venture capital firms published by VentureOne (VentureOne Corporation 2000).

To test Hypotheses 1–3, I constructed university-characteristic variables using data from The Center for Studies in the Humanities and Social Sciences at the University of Florida.[20] The Center conducts an annual ranking of top research universities in the United States starting from 2000. For this purpose, they collect and maintain data on universities from various sources. Using these data, I constructed several university-level variables that are postulated to be related to academic entrepreneurship.[21] These include measures of faculty quality (national academy membership, total faculty awards), research budget (total expenditure on research, research expenditure on science and engineering), advanced training (doctorial degrees awarded, number of post-docs), and whether the school is private.

The Center at the University of Florida has data for 616 universities. However, some variables are missing for many universities. There are a total of 150 universities for which every variable is available. I used this subset of universities to match the VentureOne data. In particular, the number of academic entrepreneurs and the number of university spin-offs are generated from the VentureOne data for each of the 150 universities. These numbers are greater than zero for 98 universities. I assign zeros to the rest of them.

To test Hypothesis 4, I constructed two variables to measure how commercially oriented a university is. They are the age of the university's Office of Technology Transfer (OTT) and the total number of patents granted to the university during 1969–2000.[22] The former is acquired through the Association of University Technology Managers (AUTM) and, when not available from AUTM, directly from OTT offices through email or phone calls; the latter is downloaded from the US Patent and Trademark Office.[23] All major research universities today have an OTT office to help their faculty with patent application and other commercialization activities. Yet the opening dates of these OTT offices vary a lot. While MIT had such an office in 1940, Princeton did not establish one until 1987. One suspects that those universities with a long tradition of facilitating entrepreneurial activities among faculty members should generate more academic entrepreneurs. The number of patents is an indicator of both how applied a university's research is and whether its faculty actively seeks to commercialize its inventions. Thus universities with a large number of patents are expected to have more academic entrepreneurs.

4. Empirical results

In this section, I empirically test Hypotheses 1–5, investigating what types of universities tend to generate more venture-backed entrepreneurs. This is primarily done in a series of multivariate analyses in which I regress the number of venture-backed entrepreneurs from a university on the university's characteristics.

4.1. Regression analysis

The variables measuring university quality are highly correlated with each other. It is very likely that a university with a distinguished faculty also spends a large amount of money on research and trains a large number of doctoral and postdoctoral students. Similarly, the measures of venture capital availability are also correlated with each other. Table 3 presents the pair-wise correlation between all the dependent and independent variables. The number of academic entrepreneurs and the number of university spin-offs have a correlation coefficient of 0.997. Thus one should expect similar results using either as the dependent variable. The national academy membership and the number of faculty awards have a correlation coefficient of 0.818; the correlation between total research expenditure and research spending on science and engineering is 0.983. All these suggest that there is a potential multi-collinearity problem if all the independent variables are included in a single regression.

Therefore, as a preliminary test, I start by regressing a university's number of academic entrepreneurs on each of the independent variables listed in Table 2, to examine which variable has the highest explanatory power (results in Table 4). Not surprisingly, in separate ordinary least squares (OLS) regressions, all university characteristics are significantly and positively correlated with the number of entrepreneurs from a university. That is, no matter which measure is used, a university tends to generate more venture-backed academic entrepreneurs if it has a better faculty, spends more on research, trains a larger number of advanced students, is closer to VC investment, or is more commercially oriented.

As shown in Table 1, the dependent variable has four outliers: Stanford has 96 venture-backed academic entrepreneurs; MIT has 85; Harvard has 58; and UC Berkeley has 38. In contrast, the distant number five, Carnegie Mellon University, has only generated 24 entrepreneurs. To make sure that the results are not sensitive to excluding the outliers, I also ran the single-variable regressions dropping Stanford, MIT, Harvard, and UC Berkeley. The results, also presented in Table 4, still show that all university-characteristic variables are significantly and positively correlated with the number of academic entrepreneurs.

However, the goodness of fit (measured by R^2) varies substantially among these regressions. The two university characteristics that are most closely related with the number of academic entrepreneurs are national academy membership and total faculty awards. This suggests that the number of a university's academic entrepreneurs has more to do with its faculty quality than its research budget or advanced training. The regression on national academy membership (using the full sample) has an R^2 higher than 0.8. That is, this variable alone explains more than 80% of the variation in the number of academic entrepreneurs across universities. Besides these two faculty quality measures, the number of post-doc appointees explains more of the variation in the dependent variable than other university characteristics. This also is a good indicator of quality of research. In the regression using the full sample, total number of patents also has a high R^2. Yet its R^2 becomes substantially smaller once the four outliers are excluded.

Table 3. Pair-wise correlation of dependent and independent variables.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
(1) No. of entrepreneurs	1												
(2) No. of spin-offs	0.9971	1											
(3) NAM99	0.9042	0.9069	1										
(4) Awards99_01	0.6835	0.6811	0.8182	1									
(5) Total-Exp91_00	0.5602	0.5551	0.6372	0.8502	1								
(6) SciEng_Exp00	0.5492	0.5441	0.6209	0.8613	0.9832	1							
(7) Doctors98_01	0.5197	0.519	0.6123	0.8009	0.7714	0.7958	1						
(8) Post-Doc_98	0.6482	0.6467	0.7767	0.7914	0.7093	0.7022	0.5893	1					
(9) Private	0.0863	0.0809	0.1795	0.0564	−0.0614	−0.0465	−0.0706	0.0821	1				
(10) Local_VC 50	0.5926	0.606	0.5699	0.3887	0.1689	0.1693	0.2209	0.3366	0.2622	1			
(11) State-VC-Firms	0.1772	0.1847	0.3274	0.1776	0.0927	0.111	0.1213	0.2179	0.1167	0.5166	1		
(12) OTT_Age	0.3551	0.3481	0.3862	0.3669	0.4524	0.4515	0.3993	0.2788	−0.0407	0.1223	0.1765	1	
(13) Patents 69_00	0.7313	0.7275	0.747	0.6123	0.6584	0.6583	0.5881	0.4117	0.1336	0.3462	0.2742	0.6198	1

Table 4. Single-variable OLS regressions. (Dependent variable: number of academic entrepreneurs from a university.)

	Independent variables										
	NAM99	Awards 99_01	Total-Exp91_00	SciEng-Exp00	Doctors 98_01	Post-Doc98	Private	Local-VC 50	State-VC-Firms	OTT-Age	Patents 69_00
Full sample											
OLS coefficient	0.27***	0.21***	4.77***	46.9***	11.2***	21.4***	5.93***	0.67***	0.05***	0.37***	3.43***
	(0.01)	(0.02)	(0.70)	(7.17)	(1.66)	(2.27)	(2.02)	(0.07)	(0.01)	(0.08)	(0.29)
R^2	0.813	0.435	0.239	0.224	0.236	0.374	0.055	0.351	0.108	0.126	0.535
No. of obs.	150	150	150	150	150	150	150	150	150	136	128
Excluding Stanford, MIT, Harvard, and UC Berkeley											
OLS coefficient	0.16***	0.10***	2.21***	22.7***	4.89***	13.4***	2.05***	0.09*	0.01***	0.09***	1.34***
	(0.01)	(0.01)	(0.25)	(2.55)	(0.65)	(1.43)	(0.77)	(0.05)	(0.004)	(0.03)	(0.19)
R^2	0.566	0.498	0.345	0.355	0.284	0.380	0.047	0.022	0.051	0.048	0.288
No. of obs.	146	146	146	146	146	146	146	146	146	132	125

Notes: Every OLS regression included a constant term, although not reported here in the table.
Standard errors are in parentheses. ***Significant at the 1% level; **significant at the 5% level; *significant at the 10% level.

Single-variable OLS regressions also show that total venture capital investment within 50 miles is significantly and positively correlated with a university's number of academic entrepreneurs. That is, a university in an area with a higher total venture capital investment indeed generates more venture-backed entrepreneurs. I also tried alternative measures of local VC investment and find that the smaller the geographic region is defined, the higher degree of correlation is observed between a university's number of entrepreneurs and local venture capital investment. Whereas total venture capital investment within a 100-mile circle explains only 17% of the variation in academic entrepreneurs, total investment within a 25-mile circle explains 48%. The number of venture capital firms at the state level – an even bigger geographic region – shows a much weaker correlation with the number of academic entrepreneurs.

As one uses smaller and smaller geographic definitions, one needs to be more and more cautious about how to interpret the coefficient of the venture capital variable. Clearly, if many academic entrepreneurs stay close to the university,[24] more venture-backed academic entrepreneurs naturally result in more venture capital investment locally. But in that case, a positive coefficient does not necessarily represent a positive effect of venture capital on academic entrepreneurship. From this point on, the analysis will use VC investment within 50 miles and total number of VC firms at the state level to measure the availability of VC locally, and use other VC measures only for sensitivity analysis.

Table 5 presents the results from multivariate regression analyses. Again, because the independent variables are highly correlated, I tried various specifications. I first used the venture capital measures as independent variables, then added different university characteristics one by one, and finally pooled all the independent variables in a single regression (models (1)–(9)). Whether a university is private or not is included in all the specifications as a control variable. Because there are many zeros in the dependent variable, I have run both OLS and Tobit regressions.[25] These two specifications give qualitatively similar results. Table 5 presents only the results from Tobit regressions.

In each of the nine regressions in Table 5, total venture capital investment within 50 miles has a positive and statistically significant coefficient. The number of VC firms at the state level, when included in the regression together with local VC investment, is never statistically significant. When the national academy membership is added to the regression in model (2), it has a positive and statistically significant coefficient, and it raises the R^2 of the regression substantially. As university characteristics are added to the regression one by one, the coefficient of the national academy membership hardly changes and remains statistically significant. A comparison between models (3)–(9) and model (2) shows that adding a group of university characteristics hardly adds any explanatory power to the simpler specification of model (2), which includes only one university characteristic – the national academy membership. Moreover, adding other university characteristics causes very little change to the magnitude of the significant coefficients in model (2). In other words, the national academy membership variable alone essentially captures all the explanatory power of the university characteristics in these regressions. In all these specifications, only one other university characteristic, number of patents, has a positive coefficient that is statistically significant (at the 10% level).

The coefficient of post-docs is statistically significant in some specifications but has the wrong sign. Sensitivity analysis showed that the significance of the post-doc variable is driven by a single outlier Harvard. This is probably because Harvard,

Table 5. Tobit regressions using the full sample. (Dependent variable: number of academic entrepreneurs from a university.)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	−3.34**	−2.79***	−2.21**	−2.60**	−2.63	−3.44***	−3.12**	−3.65**	−2.96*
	(1.50)	(0.76)	(1.03)	(1.08)	(1.11)	(1.27)	(1.24)	(1.51)	(1.50)
Local-VC 50	0.69***	0.16**	0.15**	0.17***	0.17**	0.17***	0.15**	0.17**	0.45***
	(0.12)	(0.06)	(0.06)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.09)
State-VC-Firms	0.009	−0.009	−0.009	−0.009	−0.009	−0.01	−0.009	−0.008	−0.01
	(0.02)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.008)	(0.013)
NAM99		0.28***	0.29***	0.29***	0.29***	0.29***	0.31***	0.31***	0.25***
		(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.05)
Awards99_01			−0.02	−0.05	−0.04	−0.07	−0.05	−0.05	−0.04
			(0.03)	(0.03)	(0.04)	(0.04)	(0.04)	(0.05)	(0.05)
Total-Exp91_00				0.89	1.16	0.22	0.56	0.061	−0.37
				(0.73)	(2.08)	(2.18)	(2.14)	(2.18)	(2.20)
SciEng-Exp00					−3.07	3.92	1.02	−2.02	1.08
					(22.8)	(23.3)	(22.9)	(23.8)	(25.6)
Doctors98_01						2.84	2.11	1.90	2.56
						(2.03)	(2.01)	(2.08)	(2.38)
Post-Doc98							−5.08**	−4.76*	−2.55
							(2.49)	(2.53)	(2.96)
OTT-Age								0.06	−0.03
								(0.05)	(0.06)
Patents 69_00									0.008*
									(0.005)
Private	2.97	0.46	0.37	0.59	0.60	1.29	1.12	1.68	−0.39
	(2.29)	(1.17)	(1.16)	(1.17)	(1.18)	(1.27)	(1.25)	(1.34)	(1.47)
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.057	0.222	0.223	0.224	0.225	0.227	0.231	0.234	0.259
No. of Obs.	150	150	150	150	150	150	150	136	115

Notes: Standard errors are in parentheses. ***Significant at the 1% level; **significant at the 5% level; *significant at the 10% level. Likelihood ratio chi-squared tests were conducted to test whether a model as a whole is statistically significant; p-values reported in the table shows that every model is significant.

with an extremely large medical school, consistently appoints many more post-docs than its peers.[26] For example, in 1998, the combined number of post-docs at Stanford and MIT was less than half of the number at Harvard, but each of them has many more academic entrepreneurs than Harvard.

I have done more sensitivity analysis to evaluate the robustness of the results. As discussed above, Stanford, MIT, Harvard, and UC Berkeley greatly outperformed all other schools. This raises the question of whether or not these four outliers alone drive some of the regression results. Table 6 presents regression results based on a restricted sample that excludes these four observations.[27]

When the four outliers are excluded, local venture capital investment is no longer statistically significant. In fact, neither of the two measures of venture capital availability is statistically significant in any of the regressions with other university characteristics included as independent variables (models (2)–(9) in Table 6). This suggests that the significance of the venture capital variables is derived from the four outliers, all of which have access to a rich supply of capital locally. National academy membership and total faculty awards, both measuring the quality of the faculty, are the only two variables that consistently have statistically significant coefficients. None of the other university characteristics, including the number of patents, is statistically significant. These results in Table 6 suggest that venture-backed academic entrepreneurs tend to come from universities with a first-class faculty doing high-quality research. More importantly, these results show that their entrepreneurial activities are not significantly influenced by venture capital investment near the universities, which is surprising given that this study focuses exclusively on venture-backed academic entrepreneurs.

Table 7 presents more results from sensitivity analysis. Because national academy membership and total faculty awards both measure the quality of faculty and are highly correlated, I now try the specification that includes only one of the two in the regression. As models (1) and (2) show, each of the two variables, when included in the regression separately, is statistically significant. Moreover, their coefficients and standard errors are almost identical, again indicating the high level of collinearity between these two variables. For the same reason, one may suspect that neither of the two measures of research expenditure (total research expenditure and research spending on science and engineering) is statistically significant only because they are highly collinear and are both included in a single regression. The same logic applies to the two measures of advanced training (number of doctoral degrees awarded and total number of post-docs) and the two measures of commercialization (age of OTT office and number of patents). Thus one variable in each pair is dropped from the regression to see whether the other becomes statistically significant. As the remaining columns of Table 7 show, dropping these variables hardly affects the coefficient of national academy membership or the coefficient of total faculty awards. They are still statistically significant when included in the regression separately. In fact, when national academy membership is excluded, total faculty awards is always the only university characteristic that has a statistically significant coefficient. When total faculty awards is excluded, national academy membership and total number of doctoral degree awarded are always statistically significant. Overall, the results in Table 7 again show that the quality of faculty at a university affects the number of venture-backed entrepreneurs from the university and that the availability of venture capital in the local area is not an important factor.

Table 6. Tobit regressions using the restricted sample. (Dependent variable: number of academic entrepreneurs from a university.)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Constant	0.44	−0.064	−2.08***	−2.29***	−2.40***	−2.92***	−2.93***	−2.78***	−2.86***
	(0.70)	(0.50)	(0.66)	(0.69)	(0.70)	(0.80)	(0.80)	(0.95)	(1.08)
Local-VC 50	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.08
	(0.08)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.05)	(0.08)
State-VC-Firms	0.014**	−0.001	0.002	0.002	0.003	0.003	0.003	0.004	0.008
	(0.007)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.009)
NAM99		0.18***	0.09***	0.08***	0.08***	0.08***	0.08***	0.08**	0.04
		(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
Awards99_01			0.07***	0.06**	0.07***	0.05*	0.05	0.05	0.07*
			(0.02)	(0.02)	(0.03)	(0.03)	(0.03)	(0.03)	(0.04)
Total-Exp91_00				0.46	1.62	0.96	0.97	1.04	0.78
				(0.47)	(1.29)	(1.36)	(1.36)	(1.39)	(1.58)
SciEng-Exp00					−13.8	−8.75	−9.82	−10.6	−9.08
					(14.3)	(14.7)	(15.3)	(15.9)	(19.3)
Doctors98_01						1.88	1.97	1.83	1.16
						(1.24)	(1.29)	(1.34)	(1.72)
Post-Doc98							0.91	0.28	−0.31
							(3.65)	(3.70)	(4.34)
OTT-Age								0.007	0.002
								(0.03)	(0.04)
Patents 69_00									0.002
									(0.004)
Private	2.08	0.52	1.05	1.19	1.27*	1.67**	1.67**	2.03**	1.65
	(1.11)	(0.76)	(0.75)	(0.76)	(0.76)	(0.81)	(0.81)	(0.87)	(1.07)
Prob > χ^2	0.013	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.015	0.143	0.161	0.162	0.163	0.167	0.167	0.162	0.147
No. of Obs.	146	146	146	146	146	146	146	132	112

Note: Four outliers, Stanford, MIT, Harvard, and UC Berkeley, are excluded from the regressions.
Standard errors are in parentheses. ***Significant at the 1% level; **significant at the 5% level; *significant at the 10% level. Likelihood ratio chi-squared tests were conducted to test whether a model as a whole is statistically significant; p-values reported in the table shows that every model is significant.

Table 7. Tobit regressions using the restricted sample: sensitivity analysis. (Dependent variable: number of academic entrepreneurs from a university.)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Constant	−2.78**	−3.15***	−2.99***	−3.46***	−2.99***	−3.47***	−3.00***	−3.47***	−3.00***	−3.49***
	(1.10)	(1.07)	(0.93)	(0.88)	(0.93)	(0.89)	(0.93)	(0.89)	(0.93)	(0.89)
Local-VC 50	0.11	0.07	0.09	0.05	0.08	0.07	0.08	0.08	0.09	0.08
	(0.08)	(0.08)	(0.07)	(0.08)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)	(0.07)
NAM99	0.10***		0.10***		0.10***		0.10***		0.11***	
	(0.03)		(0.03)		(0.03)		(0.03)		(0.03)	
Awards99_01		0.10***		0.10***		0.10***		0.09***		0.10***
		(0.03)		(0.03)		(0.03)		(0.03)		(0.03)
Patents 69_00	−0.0003	0.004	0.0001	0.004	0.00005	0.005	0.00007	0.005	−0.0007	0.005
	(0.004)	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
SciEng-Exp00	3.92	−14.9	2.98	−15.8	3.14	−16.3	1.68	−4.61	4.92	−3.20
	(18.4)	(18.8)	(17.9)	(18.3)	(17.9)	(18.4)	(8.09)	(8.21)	(5.98)	(6.77)
Doctors98_01	3.01**	0.73	3.26**	1.02	3.25**	1.26	3.24**	1.48	3.17**	1.39
	(1.46)	(1.69)	(1.41)	(1.62)	(1.41)	(1.61)	(1.41)	(1.58)	(1.40)	(1.55)
Post-Doc98	1.55	0.15	2.46	0.96	2.43	1.51	2.49	1.31		
	(4.32)	(4.36)	(4.26)	(4.31)	(4.25)	(4.29)	(4.20)	(4.29)		
Total-Exp91_00	−0.11	1.17	−0.14	1.15	−0.14	1.09				
	(1.53)	(1.56)	(1.51)	(1.53)	(1.51)	(1.53)				
State-VC-Firms	0.002	0.01	−0.001	0.007						
	(0.009)	(0.009)	(0.008)	(0.008)						
OTT-Age	0.001	−0.001								
	(0.04)	(0.04)								
Private	1.95*	1.79*	1.74*	1.64	1.72*	1.85*	1.73*	1.83*	1.77*	1.85*
	(1.09)	(1.08)	(1.02)	(1.00)	(1.00)	(0.98)	(0.99)	(0.98)	(0.99)	(0.98)
Prob > χ^2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pseudo R^2	0.141	0.145	0.144	0.148	0.144	0.147	0.144	0.146	0.143	0.146
No. of Obs.	112	112	125	125	125	125	125	125	125	125

Note: Four outliers, Stanford, MIT, Harvard, and UC Berkeley, are excluded from the regressions.

Standard errors are in parentheses. ***Significant at the 1% level; **significant at the 5% level; *significant at the 10% level. Likelihood ratio chi-squared tests were conducted to test whether a model as a whole is statistically significant; p-values reported in the table shows that every model is significant.

Alternative measures of local venture capital investment yielded similar results. Even total investment within 25 miles, the measure most likely to be endogenously related to the number of venture-backed entrepreneurs, does not have a statistically significant coefficient when the four outliers are excluded.

I repeated the same set of regression analyses (in Tables 4–7) using the number of university spin-offs as the dependent variable. The results are qualitatively similar and thus not reported here.

Throughout my empirical analysis, I have been focusing on the total number of academic entrepreneurs from a university rather than the number of entrepreneurs relative to the size of the university.[28] To some extent, some of the independent variables, especially the research spending variables, can be thought of as university size controls. But they are not clean size measures. For example, one may suspect that a university generated more academic entrepreneurs only because it had a larger academic staff (i.e. a larger pool of potential academic entrepreneurs). And research spending is not necessarily a good proxy of the size of academic staff. To address this concern, I tried to gather information on the number of faculty members at each university and was able to collect the data for 147 out of the 150 universities in my sample.[29]

I checked the university-size effect in two ways. First, I added 'number of faculty members' as a control variable to every regression reported in Tables 5–7. The qualitative results are not affected. Still, national academy membership and total faculty awards appear to be the statistically significant variables. When the four outliers are excluded, venture capital variables have no significant effects on academic entrepreneurship. Second, I normalize dependent and independent variables using the 'number of faculty members'. More specifically, I divide every dependent or independent variable except 'private' and 'age of Office of Technology Transfer' by the 'number of faculty members', and then run the same set of regressions using the normalized variables. The results are qualitatively similar except that when all independent variables are included (a specification corresponding to model (9) in Table 6, after adding number of patents per faculty member) no variable is statistically significant. Overall, this analysis shows that the results are robust to including university size controls.

Taken as a whole, these empirical results support Hypothesis 3. That is, universities with a high-quality research faculty tend to generate more venture-backed academic entrepreneurs. No other hypotheses are supported by the evidence.

4.2. Further discussion

The regression analyses show that entrepreneurial activities among academics are closely related to the most distinguished faculty members in universities. So why do universities with outstanding scientists tend to generate more venture-backed entrepreneurs? One possible explanation could be that a strong reputation in scientific research is a selling point that venture capitalists need. Thus venture capitalists are more willing to invest in start-ups founded by scientists from top research universities.[30] And national academy membership and total faculty awards are simply two important indicators of a school's quality of research.

Another possible reason is that outstanding scientists or their associates themselves are engaged in entrepreneurial activities once they see the commercial value of their research findings. A casual search of the Internet reveals that even among today's most distinguished scientists, starting a firm is not uncommon. Table 8 presents a partial list of Nobel Prize winners who were also entrepreneurs. Among the 36 US Nobel Laureates who won the prize in chemistry or medicine between 1993 and 2005, 13 had founded at least 14 firms.[31]

One may suspect that these Nobel Laureates' entrepreneurial activities came after their prizes. It is reasonable to believe that these scientists' research productivity had peaked before they won the prize. Thus it must be attractive for them to move into industry after the prize so that they could capitalize on their Nobel Prize fame. However, I found that most of these Nobel Laureates (10 out of 13) founded their firms before their prizes. At least for those people, their entrepreneurial activities were not triggered by the Nobel Prize.

Furthermore, I found that several of these Nobel Laureates even mentioned their entrepreneurial activities in their autobiographies/speeches submitted to the Nobel Prize archive, suggesting that they take their entrepreneurial achievement seriously. Thus, it is unlikely that these great scientists merely lent their names to, but spent

Table 8. A partial list of Nobel Laureates as entrepreneurs, 1993–2005.

Name	Affiliation	Nobel Prize	Firm founded	Founding year
H. Robert Horvitz	MIT	Medicine, 2002	NemaPharm (acquired by Sequana Therapeutics) and Idun Pharmaceuticals (merged with Apoptech)	1990, 1993
Leland Hartwell	Fred Hutchison	Medicine, 2001	Rosetta Inpharmatics (bought by Merck)	1996
K. Barry Sharpless	Scripps	Chemistry, 2001	Coelecanth (bought by Lexicon Genetics)	1996
Alan Heeger	UCSB	Chemistry, 2000	Uniax Corporation (acquried by DuPont)	1990
Paul Greengard	Rockefeller U	Medicine, 2000	Intra-Cellular Therapies	2002
Eric Kandel	Columbia	Medicine, 2000	Memory Pharmaceuticals	1998
John Pople	Northwestern	Chemistry, 1998	Gaussian	1987
Ferid Murad	UT-Houston	Medicine, 1998	Molecular Geriatrics Corporation (Acquired by Hemoxymed)	1992
Stanley B. Prusiner	UCSF	Medicine, 1997	InPro Biotechnology	2001
Richard E. Smalley	Rice	Chemistry, 1996	Carbon Nanotechnologies	2000
Alfred G. Gilman	UT-Dallas	Medicine, 1994	Regeneron Pharmaceuticals	1988
Phillip Sharp	MIT	Medicine, 1993	Biogen	1978
Robert H. Grubbs*	CalTech	Chemistry, 2005	Materia	1997

Source: Author's search on the Internet.

Note: *It is claimed that Robert Grubbs has founded four companies although I was unable to identify all of them. See, for example, http://www.neurionpharma.com/news0702grubbs.htm (accessed January 18, 2007).

little time on, their businesses. Given the list in Table 8, it is not surprising that the number of a university's academic entrepreneurs is most closely related to its number of distinguished scientists.

It is unexpected that the statistical significance of local venture capital variables is not robust. However, this is not puzzling. A comparison of locations of academic entrepreneurs' firms and locations of their academic jobs shows that not all of the academic entrepreneurs stayed close to their academic institutions (Zhang 2007b).[32] In fact, about one-third of them ended up in different states, suggesting that the availability of venture capital locally is not a decisive factor that lures academics to industry. Moreover, consider an area like Boston, which houses several universities in my sample, including Brandeis, Boston College, Boston University, Harvard, MIT, Northeastern, Tufts, and others. The number of spin-offs varies a great deal among these universities, although they have access to roughly the same local venture capital resources. The San Francisco Bay area is another example. Stanford, UC Berkeley, UC Davis, and UC Santa Cruz all enjoy the proximity to the abundant venture capital available in Silicon Valley, but show very different performance in terms of generating entrepreneurs. In the light of these examples, it is less surprising to see the regression result that very little variation of academic entrepreneurs is attributable to local venture capital.

It is worth noting that the results of this study are consistent with the findings in previous work, such as Zucker, Darby, and Armstrong (1998), Zucker, Darby, and Brewer (1998), and Di Gregorio and Shane (2003). Zucker, Darby, and co-authors showed that 'star scientists', as defined by a distinguished publication record, play a significant role in determining the location and timing of biotech firm formation. Similarly, Di Gregorio and Shane (2003) found that the number of new firms licensing a university's inventions is correlated with the intellectual eminence of the university, measured by its academic rating score in the Gourman Reports.

Both Zucker, Darby, and Brewer (1998) and Di Gregorio and Shane (2003) included venture capital variables in their regression analyses. Zucker, Darby, and Brewer found that local venture capital has no significant effects (or has significantly negative effects in some regressions) on the number of biotech firms in a region. Di Gregorio and Shane showed that the number of start-ups using university technology is not significantly correlated with the availability of venture capital locally. My result is in line with these findings. One may argue that this study's conclusion about the role of venture capital is even stronger, because neither of the previous studies is limited to venture-backed firms. What is shown here is that even venture-backed academic entrepreneurs are not attracted to industry by local venture capital.

Anecdotal evidence suggests that venture capital firms could help recruit entrepreneurs and attract start-ups from other regions (Zook 2005, 64–6). However, the distinguished scientists turned firm founders might have more leverage than other entrepreneurs when they negotiate with venture capitalists. When local venture capital is not available, an ordinary entrepreneur may have to move closer to venture capitalists. In contrast, an academic entrepreneur, with more intellectual and social capital to rely on, may be able to attract investors from other regions. It is possible that venture capitalists are willing to travel more to accommodate academic entrepreneurs instead of the other way around. This ability of academic entrepreneurs to attract venture capital from other regions could be the reason why local venture capital is not crucial in explaining academic entrepreneurship.

Some other relevant factors at the university level, such as salient entrepreneurial successes and particular university culture, are hard to measure and thus not controlled for in the empirical analyses. But they seem to be important for explaining the variation of the dependent variable among universities.[33] For example, the VentureOne data show that Carnegie Mellon University did particularly well in generating start-ups, ranking fifth in the country (as shown in Table 1). The impressive performance of Carnegie Mellon is most likely inspired by the early financial success of Lycos. Lycos is an Internet search engine developed by Michael Mauldin, a research scientist at Carnegie Mellon's School of Computer Science. The company was incorporated in June 1995. On 2 April 1996, even before the public offerings of Yahoo! and Excite, Lycos was launched on the NASDAQ. It ended the day with a market value of nearly $300 million (Lewis 1996). That instant wealth creation must have inspired many other researchers at Carnegie Mellon to follow suit. From the VentureOne data, I could identify at least 15 of the 24 entrepreneurs from Carnegie Mellon as computer scientists. Also, I found that 18 out of the 19 Carnegie Mellon spin-offs were founded after May 1996. That is, almost all these founders had witnessed Lycos and Michael Mauldin's dramatic wealth creation before they started their own ventures.[34]

Culture also matters. Two of the outliers, Stanford and MIT, have a long tradition of supporting academic entrepreneurship. This must be an important reason why they greatly outperformed other universities. At MIT, the tradition traces back to Vannevar Bush, a professor in the 1920s who co-founded Raytheon, a major US defense contractor. Bush was primarily responsible for creating a business friendly culture at MIT. His student, Frederick Terman, later transmitted the culture to Stanford (Etzkowitz 2002). In his various capacities (professor, dean of engineering, provost, and vice-president), Terman always encouraged entrepreneurial activities among faculty members and students at Stanford. The entrepreneurial culture has now been so deep-rooted at Stanford that the university even offers entrepreneurship seminars to faculty.

On the other hand, a culture that expects academic scientists to keep at arm's length from the business world may have discouraged entrepreneurial activities on some campuses. An obvious under-performer among the top US research universities is Johns Hopkins University. Johns Hopkins has one of the world's best medical schools and its annual research budget is often greater than Stanford and MIT's combined budget, but it has only six spin-offs in the data. As Feldman (1994) and Feldman and Desrochers (2003) documented, Johns Hopkins lags similar institutions along a variety of measures of technology transfer, including patents granted and patent licensing royalties in addition to firm formation. They relate this outcome to the emphasis on basic scientific research in Johns Hopkins' founding mission, the long-lasting culture of seeking 'truth for its own sake', and the lack of successful commercialization attempts in the early years that further enhanced this culture.

5. Conclusions

The university, as the producer and distributor of knowledge, is a major force of technological innovation and thus an important driver of economic growth (Rosenberg and Nelson 1994). University technology becomes incorporated into industrial practices through various channels. Entrepreneurial activities by academics constitute one particular form of technology transfer, which have not been thoroughly studied due to the limited availability of data. This paper examines a large sample of venture-backed academic entrepreneurs. A key contribution of this study is using various data sources to construct a relatively large data sample that makes a more systematic empirical analysis possible. In particular, I used the biographical information of start-up founders from a large venture capital database to identify whether an entrepreneur has had a university affiliation. Combining this rich venture capital dataset with ancillary data sources, I was able to conduct a series of multivariate analyses to investigate why some US universities generate more venture-backed academic entrepreneurs than others. My major findings include the following:

First, the number of venture-backed academic entrepreneurs from a university is primarily explained by the number of distinguished scientists at the university. An overwhelming majority of the venture-backed academic entrepreneurs are from top-tier research universities and very few are from teaching universities or colleges, suggesting that it is high-quality research that drives academic entrepreneurship. A multivariate regression analysis further confirms that better research universities tend to generate more spin-offs. Moreover, a university's national academy membership and total faculty awards are the two most significant variables in explaining its number of academic entrepreneurs. Other university characteristics, such as total research expenditure, research expenditure on science and engineering, doctoral degrees offered, and post-doc appointees, have no significant effects on the number of academic entrepreneurs once the regression includes the national academy membership and/or total faculty awards.

Second, local abundance of venture capital does not play a significant role in explaining venture-backed academic entrepreneurs once the four outliers are excluded from the regressions. Although previous research has shown similar findings, I still find this result striking because unlike any of the previous work this study focuses exclusively on venture-backed academic entrepreneurs. My analysis shows that the availability of venture capital near a university does not explain the number of academic entrepreneurs from the university even if one only counts venture-backed university spin-offs. I consider this finding the most important one in this paper.

In recent years, US state governments have implemented various policies to promote academic entrepreneurship in order to boost their local high-tech economies (Biotechnology Industry Organization 2004). A commonly used strategy is to make more venture capital available to potential entrepreneurs (Zhang 2008). My findings in this paper suggest that policies to increase venture capital accessibility alone may not work. In contrast, policies that lure prominent researchers to local universities may also help the local economy by spinning off technology companies.[35]

This study has some limitations, which should be taken into account when interpreting these findings. First, I have focused exclusively on venture-backed academic entrepreneurs. Whereas the exact proportion of all academic entrepreneurs who received venture capital is unknown, it is safe to say that it is only a small fraction. And the findings in this study may not hold for all academic entrepreneurs. Second, there are potential biases in the empirical results due to missing data. I used the biographical information in the VentureOne database to identify academic entrepreneurs. This founder information is missing for nearly 46% of the firms in the database. Furthermore, there is no information that can help gauge the potential biases caused by this sample selection process. Although there are no obvious reasons to believe that missing data are correlated with university characteristics, one has to keep this problem in mind when interpreting the results. Third, I have focused exclusively on the quantity of academic entrepreneurs and university spin-offs. One may argue that we care about the quality as much as the quantity of those entrepreneurs and spin-offs. For example, one entrepreneur may have a larger impact than another because his firm created more jobs. This study, counting the number of entrepreneurs only, does not consider any of such quality issues. These limitations are all in the nature of data constraints, which can be overcome only by collecting more and better-quality data.

Future research can be pursued in several directions. First, as already mentioned above, it would be interesting to know whether the results here remain when we also include non-venture-backed academic entrepreneurs in the analysis.

Second, it would be useful to examine potential differences at the industry level. In this study, I have lumped academic entrepreneurs in all industries. But it is conceivable that university spin-offs in different industries may be created for different reasons. For example, potential academic entrepreneurs in biotechnology and information technology industries may respond differently to the availability of local venture capital.

Third, further investigation is needed to understand exactly why a distinguished faculty is crucial in explaining the number of academic entrepreneurs. As discussed above, the statistical significance of the national academy membership and total faculty awards suggests the importance of quality research in explaining academic entrepreneurship. However, this finding is open to alternative interpretations. For example, it might be the reputation of these distinguished scientists instead of the true quality of their research that has attracted venture capital to universities. To understand the exact mechanism behind this empirical result would be important for comprehending its policy implications.

Fourth, specific university technology-transfer strategies and policies are missing from my empirical analysis, but they are clearly relevant and should be investigated in the future. For example, some universities have incubators and research parks that facilitate academic entrepreneurs. Thus a university with incubators or research parks is likely to generate more academic entrepreneurs. Also, how a university and its faculty share technology licensing fees could also have an effect. An inventor who receives a small share of royalty would have more incentive to start a firm to exploit the technology.

And finally, as we know more about what factors determine the level of academic entrepreneurship, we would also want to understand what keeps a university spin-off staying local and what may attract university spin-offs from other regions. The answers to these questions have important implications for local policymakers.

Acknowledgements

I would like to thank Nikesh Patel, whose careful and patient work on data coding has been tremendously helpful. This paper has benefited from the comments by Jon Haveman, Amy Ickowitz, Martin Kenney, Young-Choon Kim, Josh Lerner, Ting Lu, Colin Mason, David Neumark, Xue Song, Michael Teitz, Rob Valletta, Brandon Wall, Peyton Young, three anonymous referees, and seminar participants at the Public Policy Institute of California, the Center for Globalization and Information Technology at the University of California at Berkeley, the Technology Transfer Society 26th Annual Conference in Albany, New York, the

26th Annual Research Conference of the Association for Public Policy Analysis and Management (APPAM) in Atlanta, Georgia, and the Department of Economics at California State University, Hayward.

Notes

1. See Pirnay, Surlemont, and Nlemvo (2003) for a typology of university spin-offs.
2. In an early study of life scientists, Louis et al. (1989) even considered engaging in externally funded research and earning supplemental income as 'academic entrepreneurship'.
3. Data on companies founded to exploit MIT's intellectual property during 1980–96 show that about one-third of them have the university inventor as the lead entrepreneur (Shane 2004, 6–7).
4. There is also literature that studies spin-offs from existing companies that pays more attention to the process of business creation rather than technology transfer. See, for example, Klepper (2001) and Gompers, Lerner, and Scharfstein (2005).
5. McQueen and Wallmark (1982) study spin-off companies from the Chalmers University of Technology in Sweden. Smilor, Gibson, and Dietrich (1990) examine technology start-ups from the University of Texas at Austin. Using personal interviews, Steffensen, Rogers, and Speakman (2000) analyze six spin-off companies from the University of New Mexico. Kenney and Goe (2004) use survey and Internet data to compare 'professorial entrepreneurship' at UC Berkeley and Stanford.
6. According to the survey conducted by Association of University Technology Managers (2005, 28), 85 (18.6%) of 458 start-ups licensing technology from US research institutions (including universities as well as research hospitals and research institutes) received venture capital financing. Data on start-ups founded to exploit MIT's intellectual property during 1980–96 indicate that venture capitalists and angel investor groups helped finance 30% of these companies (Shane 2004, 236). In both studies, the start-ups may or may not be founded by academic entrepreneurs, but these results do suggest that only a small share of academic entrepreneurs receive venture capital. However, even if venture-backed academic entrepreneurs only constitute a small proportion of academic entrepreneurs, their start-ups likely possess a higher growth potential and may have a much greater effect on the economy than their share implies.
7. All these authors count publications at the individual researcher level rather than an aggregate level, which is straightforward. However, the analysis in this paper is conducted at the university level. Aggregating the number of publications at the university level would cause many complications because publications in different academic disciplines are hardly comparable.
8. For example, Di Gregorio and Shane (2003) included a set of policy variables to explain why some universities have attracted more start-ups to license their technologies than others. They found that some of the policies, such as inventor's share of royalties and whether the university can make equity investment, do have significant effects.
9. A 'venture-backed company' must have received some venture capital investment from venture capital firms or corporate venture capital programs. Once in the database, VentureOne tracks the company's financing from all sources, including bank loans and initial public offerings (IPOs). While I do not count bank loans or money raised through an IPO as venture capital, I do include equity investment made by non-VC corporations or 'angel investors' as venture capital in my calculations.
10. See http://www.ventureone.com/products/venturesource.html (accessed January 18, 2007).
11. As noted above, a company would be captured by the VentureOne database as long as it received venture capital financing during 1992–2001. Most of these firms secured venture capital at a very early stage. On average, a company completed its first round of VC financing 16.6 months after its founding date. See Zhang (2007a) for a more detailed description of the VentureOne dataset.
12. All founders in the data are identified by VentureOne in the data-collecting process. A founder is a person who established a start-up company. In the process of venture capital financing, the founder(s) of a start-up give up a proportion of their ownership stake in exchange for equity investment from venture capital firms.

13. For an additional 387 firms, some non-biographical information about the founder is available, but these data cannot be used to identify academic entrepreneurs. For all other firms, nothing is known about their founders. There is even no information about the number of founders each firm has.
14. The availability of founder information is not entirely random, which stems from VentureOne's database management practice. A firm enters VentureOne's database once it receives equity investment from a venture capital firm. VentureOne regularly updates the information about the venture-backed firm until it ceases operation, is acquired, or goes public. Therefore, VentureOne will follow some firms longer than others. VentureOne is more likely to obtain a firm's founder information if the firm has been followed longer. VentureOne also appears to be more likely to capture founder information for firms founded in the late 1990s, possibly because these firms tend to reveal a lot of company and founder information on their websites. For example, among firms with founder information available, 20.5% were founded before 1995; for the rest, 62.4% were founded before 1995. Indeed, firms with founder information tend to be privately held, and are less likely to be out of business, to be acquired, or to complete an IPO, which is consistent with the fact that they are younger.
15. Some founders' bios indicated working experience at some research lab or research center that may or may not belong to a university. I searched the Internet to investigate whether the lab or research center is associated with a university. If it is (e.g. Lincoln Laboratory of MIT), the founder is counted as an academic entrepreneur. Otherwise (e.g. Lawrence Livermore National Laboratory), the founder is not considered an academic entrepreneur.
16. The firm data and the founder data share a common variable, 'EntityID', by which I can match a firm with its founder when founder information is available. The matched data then can be used to compute descriptive statistics and compare academic entrepreneurs with other venture-backed start-up founders along many dimensions (see Zhang 2007b, and Zhang forthcoming).
17. If one knows the name of a firm, one could try to use alternative information sources to identify the firm's founders and find out their working experiences. However, because of confidentiality concerns, VentureOne deleted all company names and founder names and replaced them with entity and personnel ID numbers. This makes it impossible for me to supplement the VentureOne founder data.
18. Data downloaded from http://www.census.gov/geo/www/gazetteer/places2k.html (accessed January 20, 2004).
19. The distance (D) between two points (longitude1, latitutde1) and (longitude2, latitutde2) on the earth is calculated using the formula D = R*arccos [cos(longitude1-longitude2)*cos(latitude1)*cos(latitude2) + sin(latitude1)*sin(latitude2)], where R is the radius of the earth (3961 miles). See the derivation of this formula at http://www.cs.cmu.edu/~mws/lld.html (accessed March 12, 2004).
20. Data downloaded from http://thecenter.ufl.edu/ (accessed October 22, 2003).
21. Since most of the firms in the VentureOne data were founded in the 1990s, it is desirable to use independent variables in the same period or earlier. However, not all the university-characteristic variables are available in early years. Some of the variables, such as the national academy membership, are available for several years but not addable over time. So I chose the one in the earliest year. This hardly affects the results because university characteristics are fairly stable over time. For example, I run regressions using national academy membership in 1999, 2000, and 2001, and the differences are negligible.
22. Young-Choon Kim has helped with obtaining the data to construct these two variables.
23. Data downloaded from ftp://ftp.uspto.gov/pub/taf/ (accessed November 9, 2005).
24. This is likely the case especially when professorial entrepreneurs want to retain their academic positions.
25. Since the dependent variables are nonnegative integers, I also tried negative binomial regressions as a robustness check. Given the large number of zeros in the dependent variable, the zero-inflated negative binomial model seems appropriate. However, this model requires the specification of an extra equation determining whether the count is zero. If I want to add variables to the main equation one by one, how to re-specify the ancillary equation becomes a rather arbitrary decision. Thus I simply run the ordinary

negative binomial regression on the full sample and on a truncated sample dropping all the zeros. These negative binomial regressions yield results qualitatively similar to those from the Tobit regressions, although dropping all the zeros generally gives more precise estimates (with smaller standard errors) than running the negative binomial regressions on the full sample.

26. As Harvard's website shows, it has 10,647 medical school faculty, compared to only 2497 non-medical faculty (http://www.news.harvard.edu/glance/ (accessed January 18, 2007)).
27. The choice of the four outliers is rather arbitrary. It is based solely on the fact that they overwhelmingly outperformed all other universities and the suspicion that the entrepreneur-generating process in those institutions may be governed by a radically different model. While there are formal statistical procedures available to identify outliers in OLS regressions, they rely on the assumption of a correct model. In this study, I am trying many different model specifications, each of which points to a different set of outliers. Therefore, even if I follow such procedures, my choice of outliers seems equally arbitrary. The whole purpose here is to show that the statistical significance of the VC availability variable is sensitive to the including of a few observations. This point is valid even if the choice of outlier is somewhat arbitrary.
28. The successful stories of Stanford and MIT are almost always told in terms of total spin-off companies they generated. That is the reason why I chose to explain the total number of academic entrepreneurs. However, in many other contexts, 'firm formation rate' is probably a more reasonable dependent variable to use (see e.g. Reynolds, Storey, and Westhead 1994).
29. These data were hand-collected from the 13th edition of the *International handbook of universities* (International Association of Universities 1993). The handbook contains information on the number of faculty members in each university in year 1991 or 1992, which is almost exactly the starting sample period of the VentureOne database that was used to calculate the number of academic entrepreneurs from each university.
30. One would imagine that using distinguished scientists as a selling point should be most common in industries where it takes many years of R&D to develop a marketable product. Start-ups in those industries tend to lose money for many years. It is thus difficult for venture capitalists to sell their equity to other investors if they have nothing to show that the start-ups are promising. Having a star scientist as the founder will likely give investors confidence. Therefore, it is reasonable for venture capitalists to invest more in distinguished-scientist founders. The biopharmaceutical industry is an example of this type. And indeed, the VentureOne data show that more than half of the venture-backed biopharmaceutical start-ups were founded by academic entrepreneurs (Zhang 2007b).
31. One of the Nobel Laureates, Robert Grubbs, is claimed to have founded more than one firm although I was unable to name all of them. The entrepreneurial activities are by no means limited to the Nobel Laureates from the US. For example, I found that at least three Laureates from other countries also started businesses: Arvid Carlsson from Sweden (Nobel Prize in Medicine in 2000, founded Carlsson Research in 1998); Christiane Nüsslein-Volhard from Germany (Nobel Prize in Medicine in 1995, founded ARTEMIS Pharmaceuticals GmbHn (later acquired by Exelixis) in 1997); and Michael Smith from Canada (Nobel Prize in Chemistry in 1993, founded Zymos (now ZymoGenetics) in 1981). Although Michael Smith was associated with University of British Columbia in Canada when he won the Nobel Prize, the company he co-founded was actually located in the United States (Seattle, WA).
32. From the whole country's point of view, it does not matter whether an academic entrepreneur stays local or not. However, this may concern local policymakers who care about local economic benefits from the entrepreneurial activities at universities. Although I find that local venture capital availability does not explain the total number of academic entrepreneurs from a university, abundant venture capital may help keep university spin-offs from moving away or even attract such start-ups from other regions. This is an interesting question for future research.
33. This may explain why models in Tables 5–6 generally have a low pseudo R^2 and thus low explanatory power.
34. More generally, Bercovitz and Feldman (2008) have shown that a faculty member is more likely to participate in technology transfer (by disclosing inventions) if the

department chair and other faculty members at the same academic rank are active in technology transfer, clearly indicating a peer effect in entrepreneurial decisions among academics.

35. The state of Georgia provides a good example of a policy that targets potential academic entrepreneurs. The University of Georgia, Georgia Tech, and other universities in the state formed a partnership with the local government and industry, called the Georgia Research Alliance. The partnership helps these universities recruit 'eminent scholars' to Georgia. These scientists are expected to work as professors and entrepreneurs. They are even offered incubator space (Herper 2002).

References

Aldrich, H.E. 1990. Using an ecological perspective to study organizational founding rates. *Entrepreneurship Theory and Practice* 14: 7–24.

Association of University Technology Managers. 2005. AUTM U.S. Licensing Survey: FY 2004. http://www.autm.net/events/File/FY04%20Licensing%20Survey/04AUTM-US-LicSrvy-public.pdf (accessed December 28, 2005).

Audretsch, D.B., and P.E. Stephan. 1996. Company science locational links: The case of biotechnology. *American Economic Review* 86: 641–52.

Bercovitz, J., and M. Feldman. 2008. Academic entrepreneurs: Organizational change at the individual level. *Organization Science* 19: 69–89.

Biotechnology Industry Organization. 2004. *Laboratories of innovation: State bioscience initiatives 2004*. Washington, DC: Biotechnology Industry Organization.

Cochrane, J.H. 2005. The risk and return of venture capital. *Journal of Financial Economics* 75: 3–52.

Di Gregorio, D., and S. Shane. 2003. Why do some universities generate more start-ups than others? *Research Policy* 32: 209–27.

Etzkowitz, H. 2002. *MIT and the rise of entrepreneurial science*. London: Routledge.

Evans, D.S., and B. Jovanovic. 1989. An estimated model of entrepreneurial choice under liquidity constraints. *Journal of Political Economy* 97: 808–27.

Feldman, M. 1994. The university and economic development: The case of Johns Hopkins University and Baltimore. *Economic Development Quarterly* 8: 67–76.

Feldman, M., and P. Desrochers. 2003. Research universities and local economic development: Lessons from the history of the Johns Hopkins University. *Industry and Innovation* 10: 5–24.

Gibbons, J.F. 2000. The role of Stanford University: A dean's view. In *The Silicon Valley Edge*, ed. C.M. Lee, W.F. Miller, M.G. Hancock, and H.S. Rowen, 200–17. Stanford, CA: Stanford University Press.

Gompers, P., and J. Lerner. 1999. *The venture capital cycle*. Cambridge, MA: MIT Press.

Gompers, P., and J. Lerner. 2000. Money chasing deals? The impact of fund inflows on private equity valuations. *Journal of Financial Economics* 55: 281–325.

Gompers, P., J. Lerner, and D. Scharfstein. 2005. Entrepreneurial spawning: Public corporations and the genesis of new ventures, 1986–1999. *Journal of Finance* 60: 577–614.

Hellmann, T.F. 2000. Venture capitalists: The coaches of Silicon Valley. In *The Silicon Valley edge*, ed. C.M. Lee, W.F. Miller, M.G. Hancock, and H.S. Rowen, 276–94. Stanford, CA: Stanford University Press.

Herper, M. 2002. Biotech topples the ivory tower. *Forbes* May 13.

Holtz-Eakin, D., D. Joulfaian, and H.S. Rosen. 1994. Entrepreneurial decisions and liquidity constraints. *RAND Journal of Economics* 25: 334–47.

International Association of Universities. 1993. *International handbook of universities*. 13th ed. New York: Stockton Press.

Kaplan, S., B. Sensoy, and P. Strömberg. 2002. How well do venture capital databases reflect actual investments?. Unpublished manuscript, University of Chicago.

Kenney, M. 1986. *Biotechnology: The university–industrial complex*. New Haven, CT: Yale University Press.

Kenney, M., and W.R. Goe. 2004. The role of social embeddedness in professorial entrepreneurship: A comparison of electrical engineering and computer science at UC Berkeley and Stanford. *Research Policy* 33: 691–707.

Klepper, S. 2001. Employee start-ups in high-tech industries. *Industrial and Corporate Change* 10: 639–74.
Klofsten, M., and D. Jones-Evans. 2000. Comparing academic entrepreneurship in Europe – The case of Sweden and Ireland. *Small Business Economics* 14: 299–309.
Lerner, J. 1995. Venture capitalists and the oversight of private firms. *Journal of Finance* 50: 301–18.
Lewis, P.H. 1996. Yet again, Wall Street is charmed by the internet. *New York Times*, April 3.
Louis, K.S., D. Blumenthal, M.E. Gluck, and M.A. Soto. 1989. Entrepreneurs in academe: An exploration of behaviors among life scientists. *Administrative Science Quarterly* 34: 110–31.
Lowe, R., and C. Gonzalez-Brambila. 2007. Faculty entrepreneurs and research productivity. *Journal of Technology Transfer* 32: 173–94.
McQueen, D.H., and J.T. Wallmark. 1982. Spin-off companies from Chalmers University of Technology. *Technovation* 1: 305–15.
Nerkar, A., and S. Shane. 2003. When do start-ups that exploit patented academic knowledge survive? *International Journal of Industrial Organization* 21: 1391–1410.
O'Shea, R.P., T.J. Allen, A. Chevalier, and F. Roche. 2005. Entrepreneurial orientation, technology transfer and spinoff performance of US universities. *Research Policy* 34: 994–1009.
Pirnay, F., B. Surlemont, and F. Nlemvo. 2003. Toward a typology of university spin-offs. *Small Business Economics* 21: 355–69.
Reynolds, P., D.J. Storey, and P. Westhead. 1994. Cross-national comparisons of the variation in new firm formation rates. *Regional Studies* 28: 443–56.
Roberts, E.B. 1991. *Entrepreneurs in high technology: Lessons from MIT and beyond*. Oxford: Oxford University Press.
Roberts, E.B., and D.E. Malone. 1996. Policies and structures for spinning off new companies from research and development organizations. *R&D Management* 26: 17–48.
Rosenberg, N., and R.R. Nelson. 1994. American research universities and technical advance in industry. *Research Policy* 23: 323–48.
Saxenian, A. 1994. *Regional advantage: Culture and competition in Silicon Valley and Route 128*. Cambridge, MA: Harvard University Press.
Shane, S. 2004. *Academic entrepreneurship: University spinoffs and wealth creation*. Northampton, MA: Edward Elgar.
Shane, S., and D. Cable. 2002. Network ties, reputation, and the financing of new ventures. *Management Science* 48: 364–81.
Shane, S., and T. Stuart. 2002. Organizational endowments and the performance of university start-ups. *Management Science* 48: 154–70.
Shane, S., and S. Venkataraman. 2000. The promise of entrepreneurship as a field of research. *Academy of Management Review* 25: 217–26.
Smilor, R.W., D.V. Gibson, and G.B. Dietrich. 1990. University spin-out companies: Technology start-ups from UT-Austin. *Journal of Business Venturing* 5: 63–76.
Sorenson, O., and T. Stuart. 2001. Syndication networks and the spatial distribution of venture capital. *American Journal of Sociology* 106: 1546–90.
Stuart, T., and W. Ding. 2006. When do scientists become entrepreneurs? The social structural antecedents of commercial activity in the academic life sciences. *American Journal of Sociology* 112: 97–144.
Steffensen, M., E.M. Rogers, and K. Speakman. 2000. Spin-offs from research centers at a research university. *Journal of Business Venturing* 15: 93–111.
Toole, A.A., and D. Czarnitzki. 2007. Biomedical academic entrepreneurship through the SBIR program. *Journal of Economic Behavior and Organization* 63: 716–38.
Tyebjee, T.T., and A.V. Bruno. 1984. A model of venture capitalist investment activity. *Management Science* 30: 1051–66.
VentureOne Corporation. 2000. *The VentureOne venture capital sourcebook*. San Francisco, CA: VentureOne Corporation.
VentureOne Corporation. 2001. *Venture capital industry report*. San Francisco, CA: VentureOne Corporation.
Zhang, J. 2003. *High-tech start-ups and industry dynamics in Silicon Valley*. San Francisco, CA: Public Policy Institute of California.

Zhang, J. 2007a. Access to venture capital and the performance of high-tech start-ups in Silicon Valley. *Economic Development Quarterly* 21: 124–47.

Zhang, J. 2007b. A study of academic entrepreneurs using venture capital data. IZA Discussion Paper 2292.

Zhang, J. 2008. Easier access to venture capital in Silicon Valley: Some empirical evidence. In *Overcoming barriers to entrepreneurship in the United States*, ed. D. Furchtgott-Roth, 15–45. Lanham, MD: Lexington Books.

Zhang, J. Forthcoming. The performance of university spin-offs: An exploratory analysis using venture capital data. *Journal of Technology Transfer*. Prepublished online at http://www.springerlink.com/content/r81626u682v73763/fulltext.pdf (accessed August 12, 2008).

Zook, M.A. 2005. *The geography of the internet industry: Venture capital, dot-coms, and local knowledge*. Malden, MA: Blackwell Publishing.

Zucker, L.G., M.R. Darby, and J.S. Armstrong. 1998. Geographically localized knowledge: Spillovers or markets? *Economic Inquiry* 36: 65–86.

Zucker, L.G., M.R. Darby, and M.B. Brewer. 1998. Intellectual human capital and the birth of US biotechnology enterprises. *American Economic Review* 88: 290–306.