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HOW DO ENTREPRENEURIAL TECHNOLOGY FIRMS REALLY GET FINANCED, AND WHAT DIFFERENCE DOES IT MAKE?

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This paper discusses an emerging heterodoxy in the academic literature on entrepreneurial technology finance that is based on the idea of "bootstrapping." Bootstrap finance is a third approach (emphasizing funding technology ventures through revenue and other non-traditional sources), alongside the orthodoxies of traditional business finance (emphasizing debt) and contemporary venture finance (emphasizing venture capital and public equity). The paper also reports the results of an original empirical study of entrepreneurial technology firms in the bioscience-related industries in the United States. The data from the study show that "unorthodox" bootstrap financing is actually the dominant kind of financing in those high technology industries. The data are analyzed to explore industry effects, regional milieux effects, and entrepreneurial-status effects on the relative mix of bootstrap finance and the three traditional sources of finance: venture capital, public equity and debt finance. The effects on firm behavior and performance of variations in financing strategy are explored, with implications for managers of entrepreneurial technology ventures and educators concerned with technology entrepreneurship.

Keywords: Entrepreneurial technology; financial strategies; venture capital.

1. Introduction

This paper reports empirical evidence that bootstrap finance is the dominant form of financing for entrepreneurial technology firms active in biobusiness. Bootstrap finance — which includes finance from sources such as "sweat equity," personal and family funds, government grants, resources obtained through special partnerships with firms and universities, and special financial deals with suppliers and customers, but which also includes cash-flow from the sales of services and products — appears to be significantly more important as a source of capital for technological entrepreneurship than orthodox sources of finance such as venture

capital, public-equity capital, and debt financing. In addition, heavy reliance upon bootstrap finance does not normally appear to have negative effects on the business performance of firms. In fact, it appears that entrepreneurial technology firms that adopt bootstrapping strategies generally exhibit superior business performance.

These results have major implications for the strategic management of entrepreneurial technology firms. The extraordinary emphasis that is placed upon entrepreneurs gaining access to venture capital (and perhaps eventually capital from the public stock markets) — by business academics concerned with entrepreneurship, in business recipes propounded by consultants and government advisors, in policies enacted by regional economic development officials, and in the ever-more-popular business plan competitions (in which a preponderance of universities across the world now participate) — ought to be questioned. Venture capital may not only be difficult for most entrepreneurs to obtain, but also unnecessary to the success of entrepreneurial ventures. In fact, the obsession with gaining access to venture capital may even be detrimental to the majority of new ventures. The research project presented in this paper makes the case that bootstrap finance is an important phenomenon not only for "mom and pop" style entrepreneurship, which is a focus of attention in the majority of academic and government treatments of small business management, but also knowledge-intensive and high-value-adding forms of technological entrepreneurship. At a very minimum, bootstrap finance ought to be given at least as much attention as venture capital and public equity financing in research, education, practice and policy in the field of technological entrepreneurship.

2. Technological Entrepreneurship

Technological entrepreneurship has become a popular and recurring topic for discussion and empirical research by business scholars during recent decades [e.g. Quinn (1979); Romanelli (1987); Shan (1990); Roberts (1991); Jelinek and Schoonhoven (1993); Jelinek (1996); Bolland and Hofer (1998); Shane (2001); Aspelund, Berg-Utby and Skjevdal (2005)]. Its popularity as a career pathway for individuals in technology based fields who do not feel satisfied with opportunities inside established corporations, or who wish to create or manage their own enterprises, also shows no sign of waning.

Technological entrepreneurship, meaning new business activity generated through the creation of new technology based firms, has captured the imagination and attention not only of business academics, and of individuals with an entrepreneurial ambition [Bell and McNamara (1991); Garud and Karnøe (2003); Zahra, Ireland and Hitt (2000)], but also of investors and public authorities concerned about economic development [Willoughby and Blakely (1990, 1991); Segers (1992); Garnsey and Cannon-Brookes (1993); Willoughby (2000); Wintjes (2002); Venkataram (2004)]. There is now hardly a community in the developed world — whether it be a city, a sub-region, a province/state or a nation — that has not launched some kind of policy or support service to encourage regional economic development through facilitating endogenous technological entrepreneurship.

Countless studies and consulting projects in this vein have been conducted under the auspices of public authorities and regional development agencies. The vast majority concludes that a lack of appropriate entrepreneurial funding mechanisms is the fundamental obstacle to building competitive entrepreneurial technology clusters for economic development; and they typically recommend that some kind of special (often publicly supported) financing program be established to fill the "structural" financial gap. Most of the programs proposed by consultants focus on attracting new sources of venture capital, in the belief that a rich supply of local venture capital was a key (if not *the* key) ingredient in the emergence of the entrepreneurial technology economy in California's "Silicon Valley," the icon of technology communities and the model that other communities most often seek to emulate.

2.1. *Venture capital — The iconic financial solution for technological entrepreneurship*

Much of the academic literature that has emerged in parallel with these trends in business and public policy expresses the belief that venture capital, as a special form of investment funding, is a key to success in the growth of new technology enterprises [McMillan, Zemann and Subbanarasimba (1987); Pratt (1995); Amit, Brander and Zott (1998); Sapienza and De Clercq (2000); Davila, Foster and Gupta (2003); Chang (2004)] and of policies for fueling economic growth through technological innovation [Timmons and Bygrave (1986); Brett, Gibson and Smilor (1991); Roberts and Malone (1996); Manigart and Sapienza (2000); Powell, Koput, Bowie and Smith-Doerr (2002)]. In short, the availability of venture capital funding for start-up enterprises is widely viewed as essential for the development of entrepreneurial technology ventures, either at the level of regional communities or at the level of individual enterprises.

A belief in the pivotal importance of venture capital for technological entrepreneurship is expressed by business academics, not just in scholarly research but also in the design of university entrepreneurship courses and textbooks. A preponderance of textbooks and courses on the subject of business planning, used in programs associated with technology entrepreneurship, are — according to my own informal professional observations — based around the logic of trying to train students to make a case for funding by a venture capitalist. The student "business plan competition" phenomenon — which is now ubiquitous, internationally — also tends to be based around the same logic: that getting venture capital funding is the preeminent defining event in establishing a successful new enterprise.

2.2. *Capital from the public stock markets — The other iconic financial solution for technological entrepreneurship*

Alongside venture capital, many observers also point to public equity financing (i.e. raising capital through the public stock markets) as a critically important funding source for technological entrepreneurship. Public financing and venture capital financing, in this literature, are typically seen as complementary forms of

equity financing, with the quality, configuration and timing of venture capital being the defining influence on the success of public financing strategies of firms [Freear and Wetzel (1990); Houlihan Valuation Advisors/VentureOne Study (1998); Florin (2005)]. There is disagreement in the literature as to the exact nature of the impacts on post-IPO valuations and post-IPO business performance of firms of venture capital funding at various stages of enterprise growth [Lerner (1994)]. Nevertheless, there is general belief in the trade literature and the academic literature that receiving venture capital financing is normally a necessary step along the journey towards an initial public offering in the stock markets.

The twin pillars of venture capital financing and public market financing (both forms of equity financing) are generally seen, in both the business press and in popular academic treatments of the subject, as the basic foundations of entrepreneurial finance, especially in the world of technology business. However, these latter day orthodoxies in the world of entrepreneurial finance sit uncomfortably with the perspective of orthodox business school financial theory [Modigliani and Miller (1958); Brigham and Gapenski (1997)], where equity financing is typically seen as a relatively expensive source of capital, from the vantage point of the entrepreneur. In conventional theoretical finance a preference is generally expressed in favor of various forms of debt financing rather than equity financing for entrepreneurs.

The primary problem with orthodox theoretical finance, as typically taught in business schools, however, is that even though, in principle, debt financing of ventures may be more affordable in the long term than equity financing, most entrepreneurial technology firms simply just cannot get access to debt financing. This is because most providers of debt financing (i.e. banks) are, understandably, not prepared to take significant financial risks on new ventures that do not possess an established asset base or substantial revenue history. Entrepreneurial technology ventures therefore have no choice but to find other sources of capital. [Ang (1992)].

2.3. *Is venture capital (perhaps followed by capital from the public markets) really a generic financial solution for technological entrepreneurship?*

In contrast with orthodox business-school theory in managerial finance, with its normative bias towards debt financing, and the latter-day orthodoxy of entrepreneurship research, with its normative bias towards venture capital equity financing and public equity financing, a minor theme nevertheless exists in entrepreneurship research that considers the role of other — apparently less well known — sources of capital for technological entrepreneurship. A fully formed school of thought based on this minor theme probably does not yet exist; but during the last fifteen years a modest chorus of voices has been heard expressing the basic insights of this nascent, heterodox, school of thought.

In their 1989 study on the finances of the biotechnology industry in California, Willoughby & Blakely discovered that venture capital (labeled in that study as "private equity") was the primary source of funding for only 6% of firms in the industry and that public equity was the primary source of funding for only 12% of

firms in the industry [Willoughby and Blakely (1989)]. In other words, more than four fifths of the firms in California's biotechnology industry gained their primary funding from "unorthodox" sources. Given that California was home to the largest population of biotechnology firms in the world, it could hardly be concluded that the surprisingly small proportion of financing derived from venture capital and public equity was a serious problem for the State. Low levels of financing from these sources were not hampering the development of California's entrepreneurial biotechnology industry.

Subsequently, in his 1991 study of the biotechnology industry in New York, Willoughby discovered that New York's biotechnology firms obtained 22% of their total funding, on average, from private equity (venture capital combined with all other kinds of private equity) and less than 10% from public equity [Willoughby (1993)]. Debt financing accounted, on average, for about 4% of total financing. In short, he found that, on average, New York's biotechnology firms gained almost two thirds of their finance from "unorthodox" sources. These results were somewhat surprising given the overwhelming impression created by professional observers of the biotechnology industry that venture capital and public equity were the dominant sources of finance for the industry's firms [Burrill (1989)].

At around the same time that Blakely and Willoughby were conducting their research on the biotechnology industry in California Thorne published a short essay on entrepreneurial finance based on his university's advisory work with over 500 entrepreneurs in and around Pittsburgh, Pennsylvania [Thorne (1989)]. Thorne claimed that, in contrast with conventional thinking, a surprising number of new companies were financed substantially, or even entirely, from unorthodox sources of capital. He listed the following as examples of "other" sources of funding that, he claimed, were actually what tended to differentiate entrepreneurial enterprises from other kinds of enterprises: borrowing from suppliers and service providers; delaying payments due to suppliers; making special payment deals with customers; use of free, low-cost or "sweat equity" labor; making special deals for access to space; government loans and grants; partnerships with established companies and universities; and, finally, cash flow from selling services and products while R&D is being conducted on the firm's main products.

Interestingly, in line with Thorne's qualitative assertions about entrepreneurial finance in general, Willoughby [1993] found that Thorne's last category (revenue from selling services and products) was actually the single largest source of capital among all categories in New York's biotechnology industry! Despite the fact that revenue was not generally conceptualized in published financial commentaries on the biotechnology industry as a source of "capital," Willoughby found that, on average, over 40% of all capital in New York's biotechnology firms came from revenue. In other words, revenue (as a source of finance for the firms' activities) alone accounted for more than the three orthodox categories of finance — debt, public equity and venture capital — combined [Willoughby (1993)].

Freear and Wetzel, in their study of technology based firms in New England founded between 1975 and 1986, found that 38% were launched with no outside equity investors at all, and that only 32% of their total sample raised any finance

at all from venture capitalists during that period [Freear and Wetzel (1990)]. Freear and Wetzel did not include revenue as a possible source of capital in their research — presumably because "revenue" (i.e. finance generated from retained income) is, by convention, not normally thought of as "capital," even though it is included in the balance sheet along with other forms of capital in company accounts. Nevertheless, even though the main thrust of their paper was to emphasize the importance of venture capital and private equity investment from private individuals (what today would typically be labeled "angel investors"), Freear and Wetzel's research coincidentally still revealed how important other (non-conventional) sources of finance were for the establishment and development of firms in their data set.

In a thought provoking essay published more than a decade ago, based on the results of interviews with the founders of over 100 prominent *bona fide* start-up companies in the United States (mostly entrepreneurial technology firms), Bhide pointed to the importance of what he called "bootstrap finance" as the primary source of capital for start-ups [Bhide (1992)]. In his study Bhide found that retained earnings (i.e. revenue), augmented by debt, was the primary source of money to finance the growth of the firms. As a backdrop to his own original study, Bhide [1992, 109–110] made the following observation:

> *Without question, some start-ups powered by other people's money have rocketed to success. ... But the fact is that the odds against raising big money are daunting. In 1987 — a banner year — venture capitalists financed a grand total of 1729 companies, of which 112 were seed financings and 232 were start-ups. In that same year, 631000 new business incorporations were recorded. Does this disparity mean that the United States needs more tax breaks, aggressive investors, and financially sophisticated entrepreneurs to channel venture capital to more start-up companies? Not at all.*

Bhide's study uncovered evidence that the vast majority of successful entrepreneurial technology companies in the United States financed their activities through "unorthodox" bootstrapping techniques that do not rely upon venture capitalists or public financing events. He called for recognition by business school academics that special strategies are needed by entrepreneurs to deal with the special challenges of relying upon bootstrap finance rather than the more orthodox and formal sources of capital.

Bhide's observations were soon accompanied by other publications recognizing the importance, or even centrality, of bootstrap finance to entrepreneurial enterprises, including high-growth — typically technology oriented — companies [Gibson (1992); Petty and Bygrave (1993); Freear, Sohl and Wetzel (1995)].

By the mid-1990s, focused empirical research on bootstrap financing began to emerge in the literature, with the work of Van Auken and colleagues being particularly salient. Van Auken and Neeley [1996], for example, found in their study of 78 firms in the American Mid-west that used bootstrap finance for start-up capital that bootstrap finance accounted, on average, for 35% of total start-up capital. Van Auken and Neeley enigmatically chose to include both venture capital and other

equity as part of the bootstrap category, with venture capital accounting for just over 6% and other equity accounting for just over 9% of the total; whereas personal savings (accounting for over 33% of the total) was included as part of "traditional" sources of capital. However, if we exclude venture capital and other equity from the bootstrap category, and include personal savings, then Van Auken & Neely's data suggest that over half of total start-up capital in their firms was derived from sources other than conventional equity financing (including venture capital). Van Auken and Neeley also found that the degree of reliance upon bootstrap financing varied by the industry category of firms, with manufacturing firms revealing the lowest dependency upon bootstrap capital. Like Freear and Wetzel [1990] — but unlike Thorne [1989], Bhide [1992] and Willoughby [1993] — Van Auken and Neeley did not treat revenue as a possible source of bootstrap financing.

In what is probably the most rigorous and focused of studies on financial bootstrapping published to date, Winborg and Landström [2000] conducted a detailed survey of 262 small businesses in Sweden, representing 30% of the target population selected in their research of firms with less than 100 employees. Their sample was drawn from a wide diversity of industries, with roughly one fifth concentrated in manufacturing activities and one fifth concentrated in consulting and other services. They identified 32 different types of financial bootstrapping methods and found that the top five methods were all aimed at generating greater "internal funds" for firms by conserving expenditure through various intra-organizational and inter-organizational arrangements. Interestingly, in keeping with the convention set by Freear and Wetzel, and by Van Auken and Neeley, Winborg and Landström's study also excluded revenue as a category of financial bootstrapping. The one exception was their decision to include "obtain capital via manager's assignments in other businesses" (which is actually a form of revenue generation for the enterprise by generating cash through selling the services of key personnel) as an example of bootstrap capital. Twenty eight percent of firms in the study employed that technique.

An additional limitation of the Winborg and Landström study, for our present purpose of understanding financing alternatives in technological entrepreneurship, is that the study sample was not oriented towards technology based firms. However, a recent study conducted by Van Auken [2005] that was based on the Winborg and Landström methodology, but specifically designed to test differences in the bootstrapping strategies of technology based firms and non-technology based firms, has addressed that issue. Van Auken assembled a data set of 44 technology based small firms and 44 non-technology based small firms, from the American mid-West (presumably Iowa), and compared their owners' assessments of the importance of 28 different financial bootstrapping methods.

Van Auken reached two main general conclusions from his study [Van Auken, (2005)]. The first was that the basic rankings of the importance of the 28 bootstrapping methods tended to be similar amongst both groups of firms. In other words, managers of both the technology based small firms and non-technology based small firms in his sample exhibited similar overall attitudes to bootstrapping. His second main conclusion, however, was that the technology based firms tended to rank 6 of

the 28 bootstrap financing methods as more important than did the owners of the non-technology based companies. He found that owners of technology based firms placed relatively high emphasis on bootstrapping methods that minimized accounts receivable, while owners of the non-technology based firms placed relatively high emphasis on bootstrapping methods that delayed payments. In other words, the technology firms tended to emphasize methods that improved cash inflows, while the other firms tended to emphasize methods that slowed cash outflows. To paraphrase Van Auken, we could say that technology based small firms tend to be biased towards actions that generate more cash to fund the activities to which they are committed, whereas non-technology based small firms tend to be biased towards actions that reduce their level of spending.

In conclusion, during the last decade a modest body of conceptual and empirical research has appeared that questions the relevance of various financial orthodoxies for financing entrepreneurial technology firms. In tension with mainstream commentators and analysts — who emphasize either conventional forms of debt financing or contemporary forms of equity financing (venture capital and public equity financing) — the nascent heterodox school of thought outlined above emphasizes a variety of alternative forms of financing for entrepreneurial technology firms, including revenue generation and bootstrap financing (with some authors including revenue generation as part of bootstrap financing). Most of the heterodox literature is centered on the theme that while conventional forms of financing — debt financing (perhaps combined with public equity financing) or venture capital financing (perhaps combined with public equity financing) — might, in principle, be highly valuable resources for new ventures, in fact they are mostly irrelevant because (despite popular impressions to the contrary) entrepreneurial technology firms typically just cannot get access to such funds. Very recently, literature has even emerged that seriously questions whether, on average, either founders or post-VC investors really do gain long term financial value from venture capital investments in entrepreneurial firms [Florin (2005)]. The evidence and arguments that have emerged so far on the topic of alternative financing scenarios point to the need for more careful empirical research to be conducted, especially in high technology industry contexts.

2.4. *Evidence from the bioscience technology industries in the United States*

In an effort to address the above challenge, the balance of this paper will report the results of some original empirical research I have conducted on the financial profiles of firms in what are preeminently high technology industries, heavily entrepreneurial in nature, the "bioscience technology" industries in the United States.

The data to be described below were drawn from field-based empirical studies of the bioscience technology industries, in New York State and Utah, during 1996, 1997 and 1998. These years were chosen for the studies due to the fact that the author was able to obtain appropriate financial and practical support for the research from the pertinent industry and government organizations in those states during the time period in question. The studies covered not only dedicated biotechnology firms (narrowly defined) but also firms active in medical devices technology, pharmaceuticals

technology, and other fields of technology related to the life-sciences (predominantly bio-processing). This group of firms, including dedicated biotechnology firms, was labeled collectively as "bioscience technology" firms.

These two states — New York and Utah — were chosen partly because they both were homes to substantial, and growing, bioscience technology industries; but also because, despite the fact that they each possessed a substantial number of firms in the pertinent fields, they might nevertheless be considered as second-tier bioscience technology regions compared with competitor states such as California and Massachusetts. This feature made them very interesting from the point of view of economic development dynamics and also especially challenging from the point of view of entrepreneurial strategy in non-dominant regional clusters. In addition, Utah and New York exhibit sufficiently different economic, social and infrastructure profiles that they make for interesting comparisons of the effect of local technological milieux on the strategy of entrepreneurial technology firms [Willoughby, (2000)].

3. Data Collection Process

The data collection process in each state involved two main phases. The first phase, which was conducted from July 1996 to December 1996 in New York, and from March 1998 to June 1998 in Utah, consisted of an exhaustive census of all firms in each state active in bioscience technology. To be included in the study a firm had to pass through a number of analytical filters: (i) the firm had to be an identifiable *bona fide* business in its respective state, with its core operations located within that state; (ii) its dominant activity needed to be centered on at least one of the four sub-fields of bioscience technology defined above; (iii) it needed to possess a significant internal technical capability of its own within bioscience technology; (iv) it needed to either conduct R&D in bioscience technology, produce bioscience technology, employ bioscience technology as the dominant part of its business, or produce specialized technical supplies for bioscience technology; and, (v) it needed to devote the majority of its efforts to the above activities.

A master list of candidate organizations in bioscience technology was assembled for each state from multiple sources, starting with several thousand in New York and just under a thousand in Utah. Each organization on this list was subjected to two rounds of inquiries: an initial check for information consistency, plausibility and verification as to whether or not the organization was still in business or was actually located in its respective state; and a second inquiry, conducted mostly by telephone, to identify whether the firm could successfully pass through all the analytical filters indicated above (this process reduced the candidate list to about 300 firms, in the case of New York, and about 125 firms, in the case of Utah). An additional (fine-tuned) analysis of all firms which made it through the above two inquiry processes revealed the verifiable industry population in New York State to be 273 bioscience technology firms (by May 1997) and 116 bioscience technology firms in Utah (by July 1998).

The second phase consisted primarily of detailed structured questionnaire surveys of the population of firms identified in each census. This work involved

three sub-phases: (i) sending introductory letters (from the appropriate industry associations in each state) to every bioscience technology firm in the population identified for each state to introduce the study and its purposes; (ii) completing the first half of the questionnaire through a structured telephone interview with the CEO (or CEO-equivalent) of each firm; and, (iii) completing the balance of the questionnaire by obtaining completed responses by fax or mail to a set of printed interview sheets. Data were provided by each of the firms under a promise of confidentiality. It was not uncommon for this process to involve more than a dozen points of contact (by telephone, fax or letter) between myself or my research assistants and each of the firms being studied. Data were also collected on other matters about which there is insufficient space in this paper to report.

At the completion of the data collection process in New York during May 1997 telephone interviews had been completed for 125 firms, and completed interview sheets had been received from 96 firms. Comprehensive data sets (both the telephone interview and the written fax/interview sheets, combined) were completed for 94 firms. Thus, substantial data (covering between 50% to 100% of the items) was assembled for 46% of the population; comprehensive data sets (covering close to 100% of the data items) were assembled for 34% of the population. Basic identifying data were assembled for 100% of the population (273 firms).

In the case of Utah, detailed questionnaire surveys, covering the vast majority of data items, had been completed for 91 firms by the end of July 1998. Thus, the Phase Two survey sample constituted over 80% of the population. Complete "Phase One" census data (i.e. 100% of the basic identifying data) were assembled for all 116 firms in the population (i.e. the sample size for Phase One was 100% of the population size). In short, the basic data on Utah's bioscience technology industry were drawn from a completely comprehensive industry census, and the data on details of the behavior and performance of the firms were drawn from an extraordinarily high sample size, capturing the vast majority of the population.

The final data set assembled for the analysis below consisted of 184 records of valid data, drawn from 93 confirmed bioscience technology firms in New York State and 91 confirmed bioscience technology firms in Utah. One firm from New York had to be deleted from the final sample due to data quality problems, reducing the total from New York from 94 firms to 93 firms.

3.1. *Basic profile of the firms in the study sample*

The fundamental descriptive statistics of the firms in the study sample are summarized in Table 1. The average size of the firms in the sample is 146 employees; although, as is shown in Table 2, about 60% of the firms in the sample employ no more than 25 people, and only about 11% employ 300 or more people. The average age of firms in the sample is just over sixteen years; although at the time of the study 47% of the firms had been in existence for no longer than ten years and a full 24% had been in existence for no longer than five years (not shown in the tables). Eighteen percent were over 25 years old (also not shown in the tables). Over 65% of the firms in the sample are either small (no larger than 25 people) or young

Table 1. General characteristics of firms in the study sample.

	Geographical location of firms		
	New York firms	Utah firms	All firms
	Number of firms in the population		
	273	116	389
	Number of fims in the sample		
	93	*91*	*184*
Mean value of variable for firms in each region			
Employees per firm	174	118	146
Age of enterprise (years)	20.2	12.4	16.3
Revenue per firm	$62 919 093	$14 150 269	$35 431 211
Revenue per person	$852 235	$120 039	$439 543
Expenditure per firm	$22 989 369	$10 716 898	$15 437 079
Expenditure per person	$1 408 414	$128 976	$621 068
Profit per firm	−$12 909 000	$3 215 167	−$2 872 470
Profit per person	−$430 973	−$8 081	−$167 745
R&D spending per firm	$6 610 953	$2 060 329	$3 827 561
R&D spending per person	$326 096	$44 004	$153 554
Market value of firm	$23 732 960	$70 814 151	$55 724 026
Market value per person	$7 635 905	$1 199 750	$3 262 620
Percentage of firms in each category			
Public company	6%	32%	19%
Private company	91%	66%	79%
Not-for-profit organization	2%	2%	2%
Independent (discrete) firm	76%	94%	85%
Start-up firm	20%	15%	17%
Small-young firm	39%	42%	40%
Biotechnology firm	52%	25%	39%
Pharmaceuticals firm	27%	23%	25%
Medical device firm	39%	66%	52%
Bio-systems firm	20%	13%	17%
Biotechnology (only) firm	22%	10%	16%
Pharmaceuticals (only) firm	13%	11%	12%
Medical devices (only) firm	29%	52%	40%
Firms in multiple fields	34%	23%	29%

"Start-up firm" = "$\leq$ 25 people, $\leq$ 5 years"
"Small-young firm" = "$\leq$ 50 people, $\leq$ 10 years"
Source: Willoughby (1997 and 1998).

(no older than 5 years). Almost one fifth of firms in the sample (17.5%) are classic "start-up" firms (no larger than 25 people and no older than 5 years).

On average, firms based in Utah tend to be smaller and younger than those based in New York; although a larger proportion of New York's firms (about one fifth) are true start-ups. However, in both New York and Utah roughly 60% of firms are no larger than 25 people. *In short, the bioscience technology industry in both New York and Utah is predominantly young, small and entrepreneurial in character, with a significant minority of the industry constituted by true start-ups.*

The vast majority of firms in the sample (79%) are privately held (i.e. their stocks are not publicly traded), and 85% are freestanding, independent firms (i.e. they are

Table 2. Size profile (employees) and entrepreneurial status of firms.

	Geographical location of firms		
	New York	Utah	All firms
		N	
	93	*91*	*184*
Percentage of firms in each category			
Start-ups	19.6%	15.4%	17.5%
Small established firms	40.2%	44.0%	42.1%
Large emerging firms	5.4%	6.6%	6.0%
Large established firms	34.8%	34.1%	34.4%
Micro (1–5 people)	29.4%	26.4%	27.9%
Mini (6–25 people)	30.4%	33.0%	31.7%
Small (26–50 people)	7.6%	11.0%	9.3%
Mid-size (51–135 people)	12.0%	15.4%	13.7%
Large (136–299 people)	8.7%	4.4%	6.6%
Top-tier ($\geq$ 300 people)	12.0%	9.9%	10.9%

* "Small" = 25 or less people
"Emerging" = 5 or less years
"Established" = greater than 5 years
"Large" = greater than 25 people
"Start-up" = small & emerging
Source: Willoughby (1997 and 1998).

not subsidiaries of some other company). The majority of firms are therefore, we may infer, organizationally free to make their own strategic decisions. However, the fact that the industry is dominated by privately owned firms rather than publicly traded firms stands in tension with the overwhelming emphasis in both the popular business press and the academic literature on publicly traded firms in what are now widely known as the "life-sciences" industries.

The single largest industry focus of the firms is medical devices technology (52% of the sample), with 39% focused on biotechnology, 25% on pharmaceuticals, and 17% on bio-systems. The industry mix varies between each state, with biotechnology predominating in New York (52% of firms) and medical devices predominating in Utah (66% of firms). The four industry categories are not discrete (i.e. a firm may be active simultaneously in more than one industry category). Almost one third of the firms are simultaneously active in more than one industry.

These data confirm that the population of firms that is the focus of this study is indeed appropriate for addressing the issues raised in the preceding discussion about the financing of entrepreneurial technology firms.

Despite the fact that the bioscience technology industry is predominantly small, young and entrepreneurial, the average annual revenue per firm is over $35 million, and the average market value is almost $56 million. The average market value of firms in Utah is roughly triple that of firms in New York, despite the fact that firms in New York earn several times as much revenue per year, on average, as Utah firms. Bioscience technology firms in Utah are, on average, profitable — despite the popular belief that most firms in the "bio" industries are loss making.

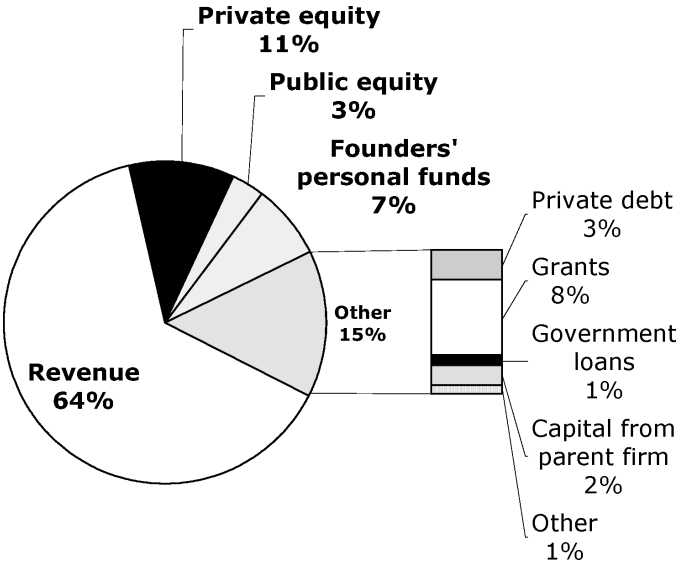

Fig. 1. Percentage of finance from each source, bioscience technology firms.

Source: Willoughby.

3.2. *How do firms in the bioscience technology industries finance their activities?*

In keeping with the indicative evidence summarized in the preceding pages of this paper, the data assembled in this study reveal that, on average, *only a small minority of the funds used to finance the activities of firms in the bioscience technology industries come from the orthodox sources of private equity, public equity and private debt.* As shown in Fig. 1, over 80% of the firms' finances come, on average, from the "unorthodox" sources of revenue and other forms of bootstrap financing. "Bootstrap finance," in Fig. 1, includes founders' personal funds, grants, government loans, and other sources (but excludes revenue). Private equity, public equity and private debt combined account, on average, for only about 17% of the finance of firms in the industry. These results call in to question the validity of the mainstream perspectives found in the academic literature and the business press on the financing of entrepreneurial technology firms.

Figure 2 breaks down the information about private equity financing from Fig. 1 in detail to reveal the relative importance of venture capital financing compared with other types of private equity financing.[a] It shows that venture capital is responsible, on average, for 8% of financing. Angel investors, however, account for the vast majority of that figure. It appears that, by the late 1990s, angle investors had

[a]Due to differences in the way financial data were organized in the New York and Utah phases of the study, detailed breakdowns of the composition of private equity financing were assembled only for the Utah firms. Calculations on venture capital as a percentage of total private equity financing are therefore based on the Utah sub-set of the total data set. Aggregate data on private equity financing were collected for both groups of firms and are equivalent in their meaning and format throughout the data set, for all firms.

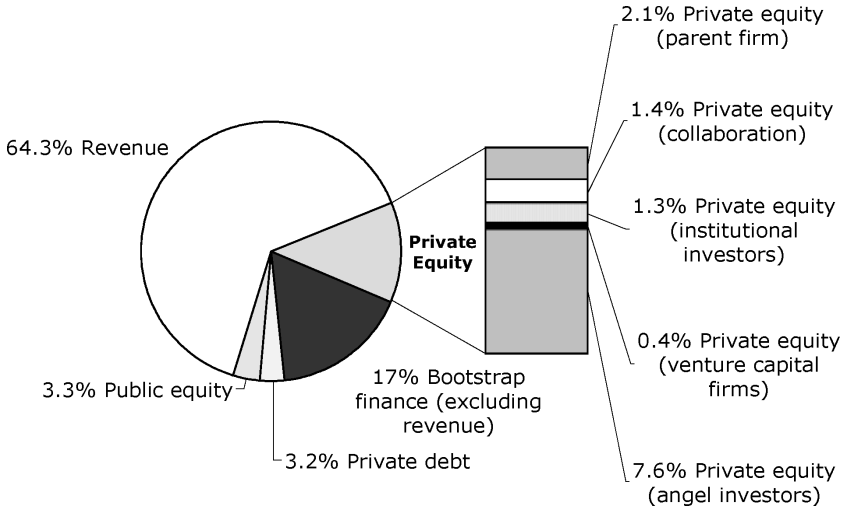

Fig. 2. Finance sources (with details of private equity).

Source: Willoughby.

Table 3. Financial profile by geographical region.

	Geographical location of firms		
	New York	Utah	All firms
		N	
	93	*91*	*184*
Mean proportion of finance derived from each source			
% Finance from revenue (total)	64.9%	63.7%	64.3%
% Finance from private equity (total)	6.7%	14.1%	10.6%
% Finance from founders' personal funds	7.5%	7.4%	7.4%
% Finance from public equity	1.5%	5.0%	3.3%
% Finance from private debt	2.8%	3.6%	3.2%
% Finance from government loans	1.4%	0.6%	1.0%
% Finance from grants	9.7%	6.0%	7.8%
% Finance from capital from parent firm	4.1%	0.3%	2.1%
% Finance from other sources	1.4%	0.3%	0.8%

Source: Willoughby (1997 and 1998).

become the true venture capitalists of the entrepreneurial bio-related technology sector. The more important story, however, is that bootstrapping sources alone (even excluding revenue) account for more than double the average percentage of finance derived from venture capital of all kinds. *If revenue is included as part of bootstrap finance then bootstrapping is responsible for more than ten times the average amount of finance derived from formal venture capital and angel investors combined.* It appears that unorthodox sources of finance are far more significant for most entrepreneurial technology firms than are orthodox sources of finance.

Table 3 reveals that the overall patterns of financing in the bioscience technology industries of the two regions from which firms in the study were drawn are roughly

similar. Utah firms do tend to raise slightly more funding from the orthodox sources of private equity, public equity and private debt than do New York firms. This is consistent with the data in Table 1 which show that a higher proportion of firms in Utah than New York have stocks that are publicly traded. When the whole picture is viewed, however, the basic financing story of the firms in each state is the same: bootstrapping, including funding activities with revenue derived from selling services and products, is the overwhelming source of finance for most bioscience technology firms, in both Utah and New York. The distinctive characteristics of regional milieux do not appear to affect this basic feature of the financial profiles of entrepreneurial technology firms.

3.3. *What impact do industry-specific factors have on financing profiles?*

The moderating influence of industry factors on the financing strategies of firms has been recognized by a number of analysts [e.g. Van Auken and Neeley (1996)]. Which industry segment a firm belongs to, within the full spectrum of fields in bioscience technology, may therefore be an influence on the financial profile of bioscience technology firms. Table 4 was assembled to test this idea, by summarizing the financial profiles of firms according to which of the four basic fields of bioscience technology they belong: biotechnology, pharmaceuticals, medical devices and bio-systems. Recognizing that firms may simultaneously belong to more than one industry segment, Table 4 also breaks down the financial profiles by whether or not a firm belongs to a combination of fields or just a single field of technology.

The results in Table 4 reveal that the basic results reported above for the whole sample of firms also apply, overall, to each industry segment. In particular, the overwhelming emphasis on revenue as a source of finance holds true for all industry segments. The actual percentage of finance derived from revenue does vary between segments, from a low in the vicinity of 55% in the case of biotechnology firms to a high approaching 70% in the case of medical devices firms. In all segments, however, more than half of the firms' finance is derived, on average, from revenue. *A core claim of this paper, that bioscience technology firms tend to finance their activities primarily from "unorthodox" sources, therefore holds true independently of the industry segment to which firms belong.*

Notwithstanding this basic observation, some interesting variations in finance across industry segments may be observed. As shown in Table 4, for example, pharmaceuticals firms tend to rely the most heavily, among firms from all other fields, on funds raised from the public stock markets. Pure pharmaceuticals firms rely more heavily on capital injected from parent firms than do firms in other industry segments, reflecting the fact that a larger proportion of these firms are subsidiaries of other corporations than is the case for the other industry segments. However, it is important to recognize that, compared with the totality of financial sources, even pharmaceuticals firms raise, on average, only a minority of their finance in these ways.

Biotechnology firms are also revealed in Table 4 to exhibit some distinctive financial features. For example, they rely relatively heavily upon private equity

Table 4. Source of finance by industry category of firms.

	Industry category											
	Biotechnology	Biotechnology (no devices)	Biotechnology only	Pharmaceuticals	Pharmaceuticals (no devices)	Pharmaceuticals only	Medical devices	Medical devices only	Bio-systems	Multiple fields	Single field only	**All firms**
	N											
	71	*57*	*29*	*46*	*39*	*22*	*96*	*74*	*31*	*53*	*131*	***184***
	Mean proportion of finance derived from each source											
% Finance from revenue (total)	55.8%	54.9%	56.8%	62.1%	58.3%	68.2%	69.3%	69.1%	61.3%	59.1%	66.4%	**64.3%**
% Finance from private equity (total)	14.2%	11.2%	11.3%	7.0%	10.8%	12.3%	8.9%	8.4%	15.6%	11.0%	9.7%	**10.6%**
% Finance from founders' personal funds	6.8%	6.6%	1.8%	9.7%	8.5%	3.4%	8.3%	7.8%	10.5%	12.7%	5.3%	**7.4%**
% Finance from public equity	2.9%	3.6%	0.0%	6.5%	5.7%	0.0%	4.2%	4.3%	0.0%	5.6%	2.4%	**3.3%**
% Finance from private debt	3.5%	3.0%	0.4%	5.0%	5.4%	1.5%	3.9%	3.6%	0.2%	5.2%	2.4%	**3.2%**
% Finance from government loans	1.7%	2.1%	1.6%	1.7%	2.0%	0.0%	0.6%	0.7%	2.5%	1.4%	0.8%	**1.0%**
% Finance from grants	12.0%	14.8%	24.3%	4.9%	5.5%	8.4%	3.2%	4.0%	5.8%	3.0%	9.7%	**7.8%**
% Finance from capital from parent firm	2.6%	3.2%	3.0%	2.9%	3.4%	6.0%	0.3%	0.4%	4.1%	1.8%	2.1%	**2.1%**
% Finance from other sources	0.4%	0.5%	0.8%	0.3%	0.3%	0.3%	1.2%	1.6%	0.0%	0.1%	1.1%	**0.8%**

Source: Willoughby (1997 and 1998).

as a source of capital, and the proportion of their finance generated through revenue is smaller than for any of the other four industry groups. In addition, "pure" biotechnology firms (i.e. biotechnology firms that are not also members of some other industry) tend to exhibit the lowest dependency of all firms on the founders' personal funds as a source of funding. Their dependence upon grants as a source of funding is also much higher than firms in all other industry segments. For example, pure biotechnology firms tend to raise about six times the amount of capital from grants, on average, than do pure medical devices firms.

Industry factors do influence the financial profiles of bioscience technology firms. However, it is also important to recognize that the basic dependence of bioscience technology firms on unorthodox sources of finance — especially revenue — holds true no matter to which industry segment they belong.

3.4. *Variations in financing according to the entrepreneurial status of firms*

Recognizing that not all entrepreneurial firms are necessarily small, and that not all small firms are equally entrepreneurial, or even necessarily entrepreneurial, the firms in the sample were divided up in to four categories, based upon a combination of their age and size, as pictured in Table 5. In interpreting the information that flows from this classification system it is important to recognize that the meaning of "small" here is not necessarily the same as occurs in much of the economics literature, or in official industry data bases, where "small" can sometimes mean that a firm employs no more than 200 people; and sometimes firms even larger than that are classified as "small businesses." Eighty six percent of firms in the sample in this study employ less than 200 people. Most of the firms classified below as "large" would actually be classified as "small" in much of the economics literature.

When the financial profiles of firms in the study sample are broken down using the above classification system, as exhibited in Table 6, it becomes apparent that the start-up firms — as would probably be expected — do exhibit a somewhat distinctive approach to obtaining finance. Start-ups rely a lot less on revenue than other categories of firms, and also exhibit the heaviest dependence of all categories of firms on grants, government loans, the personal funds of their founders, and other non-traditional sources of capital. Having said that, it is interesting to note that revenue is, on average, still the single largest source of finance for start-ups.

Table 5. Classification of the entrepreneurial status of firms.

	Age of the firm	
Size of the firm	≤ 5 years	> 5 years
≤ 25 people	Start-up firms (*17.5% of sample*)	Small established firms (*42.1% of sample*)
> 25 people	Large emerging firms (*6.0% of sample*)	Large established firms (*34.4% of sample*)

Table 6. Financial profile (including venture capital funding) by entrepreneurial status of firm.

	Entrepreneurial status of firms				
	Start-ups	Small established firms	Large emerging firms	Large established firms	All firms
			N		
	32	*77*	*11*	*63*	*184*
Mean proportion of finance derived from each source					
% Finance from revenue (total)	36.8%	66.3%	72.4%	74.7%	64.3%
% Finance from private equity (collaboration)	0.8%	2.2%	1.0%	0.0%	1.4%
% Finance from private equity (institutional investors)	3.8%	0.9%	0.0%	0.4%	1.3%
% Finance from private equity (venture capital firms)	0.0%	0.2%	0.0%	2.3%	0.4%
% Finance from private equity (angel investors)	10.7%	7.3%	8.1%	4.7%	7.6%
% Finance from founders' personal funds	17.5%	7.8%	4.0%	2.1%	7.4%
% Finance from public equity	0.0%	2.5%	0.0%	6.8%	3.3%
% Finance from private debt	4.4%	1.3%	5.0%	4.6%	3.2%
% Finance from government loans	3.7%	0.7%	0.0%	0.0%	1.0%
% Finance from grants	13.4%	10.1%	0.5%	3.0%	7.8%
% Finance from capital from parent firm	6.0%	0.3%	9.0%	1.0%	2.1%
% Finance from other sources	3.0%	0.3%	0.0%	0.4%	0.8%

* "Small" = 25 or less people
"Emerging" = 5 or less years
"Established" = greater than 5 years
"Large" = greater than 25 people
"Start-up" = small & emerging
Source: Willoughby (1997 and 1998).

Start-ups do also rely rather heavily on capital from angel investors (the second most important category for start-ups); but funds from angel investors account for only slightly over half the total generated from revenue. In summary, we could say that start-ups tend to exhibit a more diversified approach to financing their activities than do other types of bioscience technology firms. Nevertheless, start-ups do also exhibit a surprisingly heavy emphasis on revenue as a source of finance, despite their infant status as businesses.

As might be expected, capital from angel investors plays the strongest role in the case of the entrepreneurial financing strategies of start-ups (about 11%) compared with the other three categories of firms; but, surprisingly, large emerging firms follow close behind, with over 8% of their financing generated from angel investors. This result suggests that access to investments from angels has the positive benefit that it does indeed help start-ups to grow more quickly than they otherwise would have done. Large emerging firms, however, are also heavily dependent upon revenue as a source of finance (much more so, as we would expect, than is the case for start-ups).

Table 7. Financing from bootstrapping and venture capital by entrepreneurial status of firms.

	Entrepreneurial status of firms			
	Start-ups	Small established firms	Large emerging firms	Large established firms
			N	
	32	*77*	*11*	*63*
% Finance from bootstrapping	74.3%	85.3%	76.9%	80.2%
% Finance from venture capital (including angel investors)	10.7%	7.5%	8.1%	7.0%

* "Small" = 25 or less people
"Emerging" = 5 or less years
"Established" = greater than 5 years
"Large" = greater than 25 people
"Start-up" = small & emerging
Source: Willoughby (1997 and 1998).

Bootstrap finance = *revenue + grants+ founders' personal funds+ government loans+ other sources*

Venture capital funding (in the form of capital from angel investors), then, appears to be no substitute for generating revenue from sales of products and services. Rather, these two sources of finance are complementary. Success in generating one appears to lead to success in generating the other. The hope of finding investment capital from angels should therefore not be used as an excuse by start-ups for giving up on bootstrapping strategies. While some firms may be fortunate to receive a sizeable injection of venture capital during the start-up phase, most require bootstrapping as an important part of their financial portfolio.

Following the conventions of Thorne [1989], Bhide [1992] and Willoughby [1993], Table 7 groups revenue, grants, founders' personal funds, government loans and other non-orthodox sources of finance, together as bootstrap finance. The balance (i.e. "orthodox" — non-bootstrap finance) is accounted for by public equity, private equity and private debt. On average, as shown in Table 7, bootstrapping is the source of almost three quarters of the finance of start-up firms. This percentage is similar for the larger entrepreneurial firms that have been in existence for 5 years or less. The established firms (which have been in operation for longer than five years) tend, on average, to draw an even higher proportion of their finance from bootstrapping. These results are consistent with the general thrust of the emerging literature on bootstrapping that was summarized earlier in this paper.

These results also show that *the phenomenon of bootstrapping appears to be just as relevant for entrepreneurial high technology firms as it is for small businesses in general.* The results summarized in Table 7 also show that bootstrap finance is a much greater source of finance than venture capital for firms, no matter in which of the four enterprise categories they fall.

3.5. *Impact of financing strategies on the behavior and performance of firms*

The preceding analysis has affirmed the importance of bootstrapping in the financial strategies of bioscience technology firms. It seems appropriate to explore whether

or not the phenomenon of *bootstrapping* has any significance for the behavior and performance of the firms. Given that the main issue hovering below the surface in the literature on the financing of entrepreneurial technology firms seems to revolve around the availability and impact of *venture capital funding*, it therefore also seems appropriate to explore the same question *vis-à-vis* venture capital. Tables 8 and 9 are designed to assist us with this challenge.

Table 8 divides the data set in to those firms that receive at least the average proportion of their finance from bootstrapping and those that receive less than the average proportion of their finance from bootstrapping. It also repeats the same exercise for start-up firms only, so as to help us investigate whether or not the bootstrapping strategy has any special significance for start-up firms. Table 9 divides the data set in to those firms that receive venture capital funding and those that do not receive venture capital funding. It also repeats the same exercise for start-up firms only.

Table 8 reveals that firms relying upon high levels of bootstrap finance generate less expenditure in total, and less expenditure specifically on research and development, than do those with relatively low levels of bootstrap finance. These statements also hold true on a per capita basis. Presumably this pattern exists because firms heavily dependent upon bootstrap financing need to divert a large amount of their resources directly towards generating products and services for sale, at the expense of concentrating on R&D. This general pattern is even more pronounced for start-up firms.

As revealed in Table 9, firms that receive venture capital funding also generate less expenditure in total, and less expenditure specifically on research and development, than those without venture capital funding. The same pattern holds for

Table 8. Behavior and performance by level of bootstrap financing.

	% of finance from bootstrapping			
	All Firms		Start-up Firms Only	
	High	Low	High	Low
	N			
	103	*53*	*12*	*15*
Expenditure	$7 348 421	$30 728 382	$354000	$69 521 460
Expenditure per person	$566 138	$885 388	$80 632	$3 212 502
R&D spending	$1 791 368	$7 950 730	$127 400	$20 332 652
R&D spending per person	$89 988	$291 224	$52 449	$947 338
Revenue growth rate	48%	91%	18%	381%
Profit	$11 816 134	−$14 788 658	$98 000	−$66 290 210
Revenue	$19 164 555	$15 939 724	$452 000	$3 231 250
Market value	$44 148 095	$65 507 846	$21 120 000	$9 500 000
Profit per person	$85 511	−$757 362	$22 368	−$3 029 822
Revenue per person	$722 775	$106 588	$73 435	$176 902
Market value per person	$4 793 848	$1 725 273	$20 336 667	$1 730 570
% firms at break-even or above	83%	59%	100%	43%
IP items per person	2.9	2.4	1.1	1.4

Source: Willoughby.

Table 9. Behavior and performance by whether venture capital financing is received.

	Venture capital funding?			
	All firms		Start-up firms only	
	Does receive VC funding	Does not receive VC funding	Does receive VC funding	Does not receive VC funding
	N			
	13	*77*	*5*	*9*
Expenditure	$2 508 333	$11 751 430	$225 000	$742 780
Expenditure per person	$210 957	$120 416	$37 500	$73 680
R&D spending	$1 624 833	$2 106 171	$105 000	$181 869
R&D spending per person	$141 691	$33 721	$22 500	$14 397
Revenue growth rate	450%	43%	675%	292%
Profit	−$430 833	$3 476 758	$475 000	$960 553
Revenue	$2 077 500	$15 228 187	$700 000	$1 703 333
Market value	$17 214 286	$80 636 667	$4 000 000	$1 825 000
Profit per person	−$11 559	−$7 683	$33 929	$49 637
Revenue per person	$222 917	$112 733	$50 000	$123 317
Market value per person	$1 779 667	$1 125 090	$1 571 429	$325 000
% firms at break-even or above	67%	74%	100%	67%
IP items per person	6.1	3.3	3.5	1.7

Source: Willoughby.

start-up firms. Ironically, however, the reverse is true, on a per capita basis, for the whole sample (and for per capita R&D spending for the start-ups). This may be explained by the fact that firms without venture capital funding tend to employ more people than others. In the case of start-ups only, however, venture capital funding tends to be associated with higher per capita levels of R&D spending. These results suggest that venture capital funding (almost all of which, in this case, comes from angel investors) tends to help improve the *R&D productivity* (as opposed to aggregate R&D spending) of entrepreneurial technology firms only when they are in the start-up phase. Nevertheless, it is also important to temper these results with the recognition that the number of firms in this category, and the average level of R&D spending per capita, is rather small by industry standards and compared with the whole sample of firms (see Table 1 for comparison).

The salient point here is that, in general, high dependence on bootstrap finance appears to be associated with lower levels of total expenditure and lower absolute levels of R&D expenditure, for firms of any size or age; and high dependence on bootstrap finance apparently offers no advantage for R&D productivity. In fact, it appears to be negatively related with these behavior variables. On the other hand, neither does receiving venture capital funding appear to lead to higher levels of total expenditure or higher absolute levels of R&D expenditure (notwithstanding the fact that it does appear to have some impact on per capita levels of spending). Variations in the receipt of private equity funding from angel investors does appear to be associated with variations in the level of R&D activity per person in start-ups; but, increases in either bootstrapping or venture capital do not appear to have any noticeable positive impact on overall spending or R&D spending of the firms.

What, then, can we say about business performance as a whole, rather than just spending behavior? Table 8 reveals that, compared with their low bootstrapping counterparts, firms with high levels of bootstrap financing are more profitable (perhaps as a consequence of their lower spending levels) and they also enjoy bigger revenues (except in the case of start-ups, where the opposite is the case). A greater proportion of high bootstrapping firms operate at breakeven or above (83% as opposed to 59%). One hundred percent of start-up firms with high levels of bootstrap financing operate at breakeven or above, whereas only 43% of their low bootstrapping counterparts do so. High bootstrapping firms also exhibit a higher market value per person and higher levels of revenue per person; the first of these two features is even more pronounced for start-up firms, although bootstrap oriented start-ups tend to exhibit lower per capita revenue.

On average, high bootstrapping firms are profitable, whereas low bootstrapping firms are not profitable. This also holds true for both start-ups and the other categories of firms; but, in the case of start-ups, the differential in favor of high bootstrapping firms is even greater.

In contrast with these otherwise strong performance figures, the revenue growth rate of high bootstrapping firms tends, on the whole, to be lower than that of the low bootstrapping firms.

Table 9 reveals that, compared with their counterparts who lack venture capital funding, firms that do receive venture capital funding tend on average to be less profitable and enjoy lower revenues. This pattern also holds true for start-ups.

Venture capital funded firms also exhibit a lower market value, on average, and reach break-even less frequently. Start-ups receiving venture capital funding, however, seem to show superior market value and reach break-even more often. Market value per person, in contrast, tends to be relatively higher for venture capital funded firms of all ages and sizes, with this differential being even greater for start-ups. Firms receiving venture capital funding also exhibit higher revenue growth rates than their counterparts; this is true for start-ups and the more established and larger firms.

Whether or not a firm follows a bootstrapping strategy appears to have only a modest influence, if any, on the efficiency with which it generates intellectual property assets (measured as IP items, of all kinds, per person — see Table 8). Receiving venture capital funding does appear, however, to positively affect how efficient firms are in generating intellectual assets. Venture capital funded firms generate, on average, almost twice as many items of intellectual property per person as their counterparts that do not receive venture capital funding; and the same pattern holds true for start-ups (see Table 9).

In summary, it appears that the heavy reliance of bioscience technology firms on bootstrap financing strategies is, on the whole, associated with superior business performance, especially in the case of start-up firms. This result varies somewhat, depending upon which performance measures are used and upon whether or not they are calculated on a per capita basis rather than for the whole firm. This apparent positive performance effect of bootstrapping may be due to the fact that the general discipline of the bootstrapping approach tends to make firms more

prudent in their spending behaviors, and also to the fact that they appear to divert scarce resources in to revenue generating activities rather than towards blue sky research projects. Nevertheless, this behavior does not, on the whole, lead to lower efficiency in technological innovation (as measured by the level of intellectual assets generated per person). If anything, the "intellectual property productivity" of high bootstrapping firms in general appears to be even higher than that of the low bootstrapping firms — except in the case of start-ups, where there does appear to be some trade-off at work between the level of short term R&D activity and short term financial survival. The overall positive impact of bootstrap finance might also be explained by the stimulus to innovation and business prowess generated by closer relationships to customers, with bootstrap finance creating pressure for faster development of relationships with customers [von Hippel (1976, 1998); Baldwin *et al.* (2006)].

There is a positive relationship between the receipt of venture capital and the efficiency with which firms appear to invent technology (as measured by the volume of discrete intellectual assets generated, including patents). On the whole, however, the receipt of venture capital (primarily from angel investors) does not appear to improve overall business performance. The main exception to this pattern is that start-ups (and not other categories of firms) that receive venture capital funding do appear, on average, to achieve higher market values, on both a per capita basis and a per firm basis. These positive aspects of venture funding need to be weighed against the fact that only a minority of bioscience technology firms appears able to receive venture capital funding. In addition the business value of the venture capital funding would appear to be realizable only if the firm, or part of the firm's equity, is sold.

From a business point of view, bootstrap finance appears on average to contribute more substantially to the work of bioscience technology firms — across the whole industry — than does venture capital finance. At a very minimum, there appears to be no overwhelming penalty to firms to following a bootstrapping strategy. More likely, there are real business advantages to the strategy. In any case, it is not at all obvious that most of the firms would have the option of funding their growth primarily through venture capital, even if they wished to do so.

3.6. *Main conclusions from the empirical research*

The data collected and analyzed in this research project reveal that bioscience technology firms in two significant regions of the bioscience technology industries in the United States raise their funds from a wide variety of sources. A surprisingly small minority of their finance is derived, on average, from the three dominant orthodox sources of finance: private equity (especially venture capital), public equity (the stock market) and private debt (banks). The majority of finance for the firms in the study sample comes from what has come to be known as "bootstrap" finance, the largest single component of which is revenue from the sale of services and products.

Industry factors do play some role in determining the particular mix of financing sources adopted by bioscience technology firms. The overall pattern — which emphasizes bootstrap finance, with a heavy emphasis on revenue generated by the

firm itself — seems to be robust, however, with only minor variations observable according to which segment of bioscience technology a firm belongs.

There are some regional variations in the character of the bioscience technology industry, as revealed in the study sample. Nevertheless, the regional location of a firm does not in itself appear to play a major role in determining the overall financial structure of the industry, *vis-à-vis* the fundamental role of revenue as a source of finance. There does appear to be some impact of regional milieux on the relative weights of private equity, public equity and debt financing for firms. The fundamental importance of bootstrap finance is not substantially altered, however, by these regional variations.

Start-up firms tend to rely less heavily than other firms on bootstrapping for their finance, and within the bootstrap category they typically rely less heavily on revenue and more heavily on other forms of bootstrap finance than older and larger firms. Nevertheless, start-up firms do tend to benefit more substantially in business terms from a high bootstrap strategy than do other firms.

In summary, bootstrapping appears to be the dominant source of finance for firms in the bioscience technology industries; and there do not appear to be any major disadvantages, from the perspective of business performance, for firms that follow a strategy that emphasizes bootstrapping.

3.7. *Implications for theory*

Most of the literature dealing with the financing of entrepreneurial technology firms emphasizes the twin pillars of venture capital and capital from the public stock markets as the most important sources of finance for supporting the growth of the firms and their associated high technology regional economies. This theme sits in an uneasy tension with orthodox business school financial theory, which tends to see equity finance as being relatively expensive for entrepreneurs, in the long term, compared with debt financing.

However, a minor theme has emerged in the entrepreneurship literature during the last one and a half decades that emphasizes a "third way" by which entrepreneurial technology firms might be financed, namely, bootstrap finance. At present the advocates of bootstrapping as a financial strategy probably represent no more than a nascent heterodoxy, rather than a fully-fledged school of thought. As a consequence, the theory behind the "third way" is, at this stage, rather thin. Most of the evidence in support of bootstrapping as a viable strategy for entrepreneurial firms is empirical, and, thus far, only a handful of studies appear to have been produced on the subject. Researchers operating outside the formal domain of academic finance have conducted most of that work. There is, therefore, a need for academic research to produce formal theoretical frameworks to help explain the phenomena reported in this paper and its predecessors in the area of bootstrap finance.

There may be value in scholars of finance from business schools, especially those in managerial finance, to participate in this endeavor. The exercise will most likely be productive if it is an interdisciplinary effort involving researchers from other fields, including entrepreneurial strategy, technology management, economic geography, and accounting.

3.8. *Implications for future research*

This study is limited by the fact that it deals with one high technology industry area only, namely, what has been labeled here as the "bioscience technology" industry. It comprises firms in the biotechnology, pharmaceuticals, medical devices, and bio-systems industries. Firms in this broad domain are often active in more than one of its sub-industries simultaneously. The broad domain of bioscience technology is now more frequently known as the "life sciences" industry, or simple as "biobusiness." Nevertheless, despite the complex and interdisciplinary nature of bioscience technology, it would be valuable if further studies along the lines of the one summarized in this paper were conducted for firms in high technology fields other than those directly related to the life sciences and biotechnology.

The firms in the data set reviewed in this study were drawn from two regions in the United States that are homes to substantial bioscience technology industries. It would be valuable if further studies along the lines of the one summarized in this paper were conducted for firms in the bioscience technology industry elsewhere in the United States and the world.

Most published research on financial aspects of the entrepreneurial technology world is based on publicly available information on publicly traded firms. Most entrepreneurial technology firms, however, do not trade their stocks on the public markets. This fact calls into question the relevance of most financial research for the strategies of the majority of entrepreneurial technology firms. This study points to the need for more financial research on technology companies based on data sets that more realistically reflect the true nature of the entrepreneurial sector, namely, that most firms are private companies rather than public companies.

3.9. *Implications for managerial practice*

Bootstrapping strategies are a central element of the overall financing strategy of entrepreneurial technology firms. Bootstrapping strategies also incorporate a variety of financial and behavioral components and require considerable flexibility and nuance in their execution. The prominence of bootstrap finance, even in high technology sectors such as bioscience technology, means that narrow strategic recipes, such as those that focus on obtaining access to venture capital, are just too simplistic for the real world of entrepreneurial technology. It appears that many managers of entrepreneurial technology firms are already aware of this, either by intuition or through common sense. It is important that management educators do not create even more problems for such entrepreneurs through clumsy application of poorly grounded financial recipes.

It is incumbent upon scholars of management to carefully study what managers of entrepreneurial technology firms actually do to finance their activities; and then, after reflecting about the lessons learned, to develop new ideas and new frameworks for education and training in entrepreneurial strategy that will really be helpful to managers of technology start-ups trying to find their way in the maelstrom of money within the terrain of technology.

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