The Role of Venture Capitalists in Financing and Developing High-Technology Start-ups

by

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ABSTRACT

This dissertation addresses the interaction between venture capitalists (VCs) and start-up development through three essays. A common theme is that VCs serve important extra-financial and information brokering roles. In the first essay, using the setting of entrepreneurs obtaining financing from VCs, I empirically evaluate a market for affiliation with prominent partners. I hypothesize that the price for association is increasing in the prominence of the affiliation partner. By assembling a novel sample of start-ups with multiple financing offers, I analyze offers made by competing VCs at the first professional round of funding, holding characteristics of the start-up fixed. The estimated effects are economically significant, with a doubling of a VC’s industrial deal experience in a start-up’s industry, for example, associated with a six to nineteen percent discount in price paid to acquire start-up equity.

The second essay, co-authored with Joshua Gans and Scott Stern, explores the determinants of commercialization strategy for start-up innovators by examining whether start-ups earn their returns to innovation through product market competition as opposed to cooperation with more established firms (either through licensing, strategic alliances or outright acquisition). Three variables in the start-up’s commercialization environment affect the relative returns to a cooperative commercialization strategy: (a) the control of intellectual property rights (IPR), (b) low transaction costs, and (c) the cost of sunk assets associated with product market entry. While the main finding is that control of IPR increases the relative return to cooperation over competition, we also find evidence that association with VC facilitates a cooperative strategy by lowering transaction costs to accessing information channels.

The final essay examines the evolution of VC practices at one early and influential VC firm, American Research & Development (ARD), and the entry of alternative organizational forms in financing and developing early stage firms. The ARD case highlights the important practices associated with VC, and ARD’s
evolution of financing practices. Structural and business environment factors of VC seem to both leave a funding gap for early stage start-ups and concentrate investments, as measured by industrial sector and geographic location. Alternative organizational forms seem to have arisen to address these opportunities.

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Chapter One

The Role of Venture Capital in Financing and Developing High-Technology Start-ups: Introduction and Overview

1.1 Background

This dissertation studies the interaction between venture capitalists and start-up development through three essays. The first two essays in this dissertation hold the view that venture capitalists (VCs) have become more than strictly an institution of financial intermediation, investing capital from financial institutions to capital-constrained entrepreneurs. In addition to their important monitoring role, VCs offer both reputational value and other purely informational benefits to the start-ups they fund. Chapter 2 establishes the basic result that start-ups face a higher price for affiliation with more prominent VCs, a finding consistent with the view that venture capitalists' experience, information network, and/or reputation may be more distinctive than their financial capital. Chapter 3, in examining the determinants of start-up commercialization strategy, finds that VCs are associated with lower transaction costs in achieving a "cooperative" start-up strategy. This finding is consistent with a view that VCs act as information brokers between private start-ups and product market incumbents. By neutralizing the potential effect of capital market constraints to start-ups, these two chapters study the pure VC information effect. The final essay in the dissertation, Chapter 4, places some context on the VC institution by exploring its financing practices and how they evolved in an early VC firm, American Research & Development. The chapter also offers insights into the entry of alternative organizational forms for entrepreneurial finance by exploring a hypothesis of how institutional and business environment factors may have contributed to such
entry. These essays are especially topical given the rapid rise of capital committed to-and invested-by venture capital (VC) throughout the 1990s (see Figure 1A).

Much of the venture capital literature has focused on how VCs solve a variety of information asymmetry and incentive problems associated with funding entrepreneurs (e.g., Hellman, 1998; Gompers and Lerner, 1999). This literature tends to concentrate on VC mechanisms for effective start-up governance, particularly staging of investments (e.g., Gompers, 1995), monitoring through corporate boards (e.g., Lerner, 1995), and designing contracts to limit agency problems (e.g., Kaplan and Strömberg, 2000a).

The purely informational role of VCs in start-up development has not received as much attention by economists, however. VCs maintain a number of important relationships contributing to their role as brokers of information (see Figure 1B for a stylized representation of these relationships). Work in organizational sociology suggests that individuals who serve as bridges or brokers between otherwise disconnected parties may earn rents as a result of their unique structural position in the social and information network (Burt, 1992). Researchers in this tradition of network analysis have found performance effects associated with affiliation with prominent actors (e.g., Stuart, Hoang, and Hybels, 1999). However, these network studies tend to provide an incomplete treatment of the costs associated with affiliation with reputable actors. This dissertation is related to a small empirical literature on the extra-financial VC role of start-up development. For example, Hellman and Puri (2001) find a contingent role for VCs that is dependent upon the performance of their portfolio companies, exercising corporate control when the start-up is in a bad “state” but aiding in, for example, human resource recruitment in a good state. The research in this dissertation builds on these strands of both the economics and sociology literatures.

Micro-econometric empirical research has traditionally been difficult in the field of technology entrepreneurship, however, because data constraints on private start-ups are usually binding. In particular, obtaining sensitive information from
companies not compelled to reveal such information is challenging due to the potential of breaching the start-up’s competitive positioning (Gompers and Lerner, 1999; Hellman and Puri, 2001). Collecting both detailed offer-level (Chapter 2) and project-level (Chapter 3) information calls for a labor intensive survey-derived data collection process. As Henderson and Cockburn (1996) show, however, project-level empirical analysis can be illuminating relative to analysis at a higher level of aggregation. The “micro” data collection approach follows Hellman and Puri’s (2000; 2001) use of the Stanford Project on Emerging Companies sample to explore the role of VCs in start-up development.

1.2 Overview of the Dissertation Essays

Table 1.1 provides a brief summary of the dissertation chapters, all of which explore a facet of financing and developing early stage, technology intensive start-ups. This section gives an overview these chapters and highlights the contribution of each to the literature.

1.2.1 Do Entrepreneurs Pay for Affiliation?

There has been growing interest in the strategy literature with the prospect of economic benefits resulting from possessing social status (Podolny, 1993) and association with high status affiliates (Stuart, Hoang, and Hybels, 1999). Affiliation with prominent actors is particularly relevant to early stage high-tech entrepreneurs because gaining external financial resources may be difficult when the existing assets of the start-up are intangible and knowledge-based. This research stream is incomplete, however, because the costs of affiliating with prominent actors are not fully considered or systematically analyzed empirically. This essay therefore explores the market for affiliation in the setting of high-tech entrepreneurs obtaining financing from VCs. This empirical setting is well suited to studying whether entrepreneurs pay a premium to affiliate with prominent VCs (accepting a smaller cash infusion for a
given amount of start-up equity). Due to the tremendous increase in the supply of venture capital in the second half of the 1990s, the existence of a menu of price offers by VCs (each with varying prominence) for a given start-up has become more likely. On its face, the dollar value of financial capital to high-tech entrepreneurs would seem to be the same, regardless of source. If entrepreneurs expect productivity differences as a result of accepting capital from highly prominent and experienced VCs, however, we may see entrepreneurs accepting lower valuations for affiliation.

This hypothesis is tested by analyzing a set of start-ups which received multiple offers for financing the first professional round. This method allows a high degree of statistical control because the characteristics of the start-up can be held constant, allowing only differences in VC prominence to explain inter-offer variation in price for start-up equity. Analysis of a novel sample of 148 alternate offers received by a set of 51 high-tech start-ups confirms the key hypothesis. Estimated coefficients suggest that a doubling of a VC’s industrial sector deal experience in a start-up’s industrial sector, for example, is associated with a six to nineteen percent discount in VC price offered for start-up equity. The main contribution of this essay is to present empirical evidence that affiliation is an ordinary economic good for which actors seeking association will face a price-prominence trade off. This is true whether the entrepreneurs are seeking status itself or are indeed pursuing other attributes that they believe to be associated with the status providers. The paper also joins a small empirical literature that examines the demand-for, rather than the supply of, venture capital.

1.2.2 When Does Start-up Innovation Spur the Gale of Creative Destruction?

Recent research in the economics of technical change has recognized that rather than the act of invention itself, one of the major challenges facing technology-oriented start-ups is converting an invention into a commercialized product (Teece, 1986; Gans and Stern, 2001). Indeed, as analysts such as Rosenberg (1994) point out, technical success is a necessary but not sufficient condition for commercial success.
Chapter 3, co-authored with Joshua Gans and Scott Stern, tackles this issue head-on by studying the determinants of alternative start-up commercialization paths in earning returns from their inventions. This choice—commercializing the invention through competition with product market incumbents or cooperating with them (either through licensing, strategic alliances or outright acquisition)—has implications for the incumbent’s product market position.

After developing a simple model of the start-up choice between product market competition and cooperation with established companies in commercializing invention, we test our empirical prediction in a novel sample of start-ups. We evaluate whether cooperation is associated with (a) innovations that receive formal IP protection (e.g., a patent), (b) firms with access to a network of contacts (e.g., through a relationship with a venture capitalist), and (c) environments where ownership of complementary assets by the start-up is perceived as ineffective in earning profits from innovation. To test these hypotheses, we examine a novel sample of 118 technology-based projects divided almost evenly between two mechanisms of external entrepreneurial finance, through VCs and the U.S. Small Business Innovative Research program. Dividing the sample in this way incorporates variation in the costs of identifying and contracting with partners while maintaining the ability to evaluate the impact of IP strength and sunk costs across a cross-section of firms.

We find that each factor is associated with a quantitatively significant effect on the probability of cooperation. Specifically, we find that commercialization through the “market for ideas” – the cooperative strategy – is increasing in the strength of intellectual property held by the start-up, the relative cost of controlling complementary assets necessary to commercialize an invention, and the presence of venture capitalists who reduce the transactions costs associated with locating appropriate cooperation partners. Under cooperation, the overall (negotiated) returns to a start-up innovator reflect both the value of their proprietary knowledge as well as their ability to threaten the established firm with competitive entry. The combination
of these two effects makes the payoffs to cooperation more sensitive to the strength of IP than the payoffs to competition.

If an ideas market functions efficiently, incumbents can contract for innovations from start-ups (who then serve as technology suppliers) and so foreclose on a potentially important form of competition. The main contribution of this essay, therefore, is to establish the position that start-up commercialization strategy choice is endogenous to its commercialization environment.

1.2.3 Why is Entrepreneurial Finance Organized the Way it is?

As financial institutions meant to address capital constraints to start-ups, organized venture capital has become an important part of the U.S. innovation system. Neither the practices associated with financing early stage ventures, nor the organizational form of providing entrepreneurial finance has been constant over time, however. Exploring the evolution of VC financing practices may offer insight into the challenges of funding early stage entrepreneurs and how those challenges have changed over time. Likewise, examining the entry of alternate organizational forms of entrepreneurial finance may shed light on the structure and practices of VC that have enabled entry. The final essay, Chapter 4, therefore examines the evolution of VC practices at one early and influential VC firm, American Research & Development (ARD), and the entry of alternative organizational forms in financing and developing early stage high tech firms. The ARD case highlights the important practices associated with the institution of venture capital, and ARD’s evolution of financing practices. For example, ARD seemed to be most effective when it funded R&D-based organizations located in Massachusetts. The essay then examines the entry of alternate organizational forms in provisioning early stage entrepreneurial finance, ranging from U.S. federal government efforts to more recent organized efforts such as angel groups and business incubators. The thesis of this section is that entry of new organizational forms resulted from opportunities afforded by both the institutional structure of VC, as well as the business environment faced by VCs. Specifically,
venture capitalists seem to have left a "gap" for financing early stage ventures and have tended to concentrate their investments by industry and geography. A qualitative case study of the experience of funding cardiovascular medical device start-ups illustrates the funding gap.

1.3 Conclusion and Future Directions of Research

Taken as a whole, the three essays in this dissertation improve our understanding of the extra-financial and information brokering roles that venture capital as an institution plays in developing early stage, high technology companies. I do this by examining in turn, the demand by entrepreneurs for accessing a prominent VC's capital and services (when faced with alternative choices), the commercialization strategy effects of being backed by VC, and the set of institutional structures associated with venture capital.

By collecting detailed firm- and project-level data on two groups of start-up companies, this dissertation has provided micro-econometric evidence in areas previously un- or under-studied. Due to the relatively high cost of obtaining data to empirically study research questions in entrepreneurial strategy and finance, these studies rely on tight linkages between research question and methodology.

The essays in this dissertation are not without their limitations. At an aggregated level, the two empirical chapters, by relying on data from survey instruments, suffer from shortcomings inherent to these types of data. First, because respondents were asked about events taking place in the past, the data may suffer from retrospection bias and measurement error. Furthermore, particularly for questions involving more subjective responses, the data may not be comparable across observations. The essays discuss (imperfect) solutions to these problems in each of the settings. The final essay adopts a more qualitative approach, in the tradition of institutional economics, to explaining evolution of financing practices in VC and entry of alternate organizational forms of entrepreneurial finance. The
primary limitation to this approach is that a range of alternative explanations cannot be eliminated. However, suggestive case-based evidence underpins the explanation offered.

The research presented in this dissertation exposes areas warranting future investigation. The first group of these future studies is centered on performance issues following directly from the dissertation chapters. For example, are there performance effects for start-ups paying a premium to access the capital of more experienced VCs? Do start-ups choosing a cooperative commercialization strategy earn different returns relative to a product market competition strategy? And are there different performance implications associated with different organizational forms of entrepreneurial finance? A second cluster of research projects center on deepening our understanding of the role and source of intellectual property for technology-oriented start-ups. One setting in which this may be important, for example, is in facilitating cross-licensing (Hall and Ham, 2001) or other cooperative commercialization strategies such as strategic alliances. In addition, can patenting behavior, including evidence from patent citations, provide insight into the knowledge flows responsible for start-up activity and performance? More generally, my long-range research agenda is dual-fold: (1) understanding the similarities and differences of technology strategy for start-ups versus more established firms, and (2) understanding the emergence and evolution of industries.
Figure 1A. U.S. Venture Capital Commitments and Disbursements, 1965-2000

Source: Venture Economics
Figure 1B. Stylized Venture Capital Relationships
<table>
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<td>Primary and secondary ARD documents; field interviews of important actors in the CMD industry over time</td>
</tr>
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<td></td>
<td>Entrepreneurs seem willing to pay a premium to access capital from more prominent VCs, as measured by entrepreneur-rated VC reputation and two objective measures: VC industry-specific experience and VC IPO experience.</td>
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Chapter Two

Do Entrepreneurs Pay for Affiliation?

2.1 Introduction

A central issue for early stage high-tech entrepreneurs is obtaining external resources when the assets of the start-up are intangible and knowledge-based. Particularly for first time entrepreneurs, convincing external resource providers such as venture capitalists to provide risk capital may be challenging. The literature contains two main lines of research for overcoming this problem. One research stream has concentrated on designing institutional structures to permit financing early stage ventures. This contractual- and monitoring-based approach is aimed at solving potential agency problems between investors and entrepreneurs (e.g., Admati and Pfleiderer, 1994; Hellman, 1998; Gompers and Lerner, 1999; Kaplan and Strömberg, 2000a). A second research stream has suggested that when the quality of a start-up cannot be directly observed, external actors rely on the quality of the start-up’s affiliates as a signal for the start-up’s own quality (e.g., Megginson and Weiss, 1991; Podolny, 1993; Stuart, Hoang and Hybels, 1999). This certification-based approach may help legitimate start-ups and entrepreneurs without a prior track record.

While the first research stream emphasizes the venture capitalist’s problem (designing the appropriate mechanisms), the second highlights the entrepreneur’s problem more directly (affiliation with highly prominent partners). This second strand of research is incomplete, however, because the costs of affiliating with prominent actors are not fully considered or systematically analyzed empirically. For example, the prescriptive advice to start-up entrepreneurs of affiliating with the highest status partner possible (Stuart, Hoang, and Hybels, 1999: 347) seems strong given that calculations of returns to status that do not fully take into account the costs of
affiliation will be overestimated. Indeed, demand for affiliation with prominent actors is likely to vary with the cost of such association. More generally, because affiliation with highly prominent partners confers performance benefits (e.g., Megginson and Weiss, 1991; Zuckerman, 1999; Stuart, Hoang and Hybels, 1999), status cannot be freely accessed, for otherwise prominent certification agents would not have incentives to invest in acquiring status in the first place (Shapiro, 1983). The extant research on the market for certification has only established general bounds. Statements on the supply of certification have been generally limited to an acknowledgement that suppliers of status will not want to provide affiliation to entities which will damage their reputation (Podolny, 1993). Likewise, on the demand side, researchers have argued that only those organizations which will benefit most from certification will accept the terms of a stringent supply contract (Lazear, 1986; Kaplan and Strömberg, 2000a).

Consequently, this essay explores two inter-linked questions: Is there a market for affiliation with prominent partners? If so, what are the prices for such affiliation? That there should be a market for affiliation with an accompanying price schedule seems intuitive. Different actors will have differing preferences for accessing status and heterogeneous beliefs about the marginal benefit to doing so. In contrast to much of the prior literature, which has argued that status pays, this paper asks a logically prior question of whether certification targets have to pay a premium to access high status certification agents: do entrepreneurs pay (a premium) for affiliation?

Entrepreneurial demand for affiliation with venture capitalists provides an excellent empirical setting to explore this research question for two reasons. First, because VCs can certify and start-ups need to be certified, the exchange nature of the relationship provides a natural marketplace for affiliation. Secondly, due to the tremendous increase in the supply of venture capital in the second half of the 1990s1,

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1 Disbursements to start-ups from VCs, which totaled just $665M in 1980 and $2.3B in 1990, skyrocketed to over $100B in 2000 (these figures are in 1999 dollars and come from the Venture Economics web site).
the situation of “money chasing deals” makes observing a menu of price offers by VCs with varying prominence more likely.

In this paper, I examine the empirical relationship between the price per equity unit that venture capitalists offer for start-up equity and correlates of VC prominence and experience. I hypothesize a negative relationship because entrepreneurs should be willing to pay a higher price to be affiliated with more prominent venture capitalists. This main hypothesis, which implies that status affiliation (and/or its correlates) is an ordinary economic good, cannot be empirically tested in a straightforward way, however. First, as with any study of private firms, acquiring detailed data at the firm- and offer-level is challenging. Second, a simple cross sectional study regressing accepted offer prices on the correlates of VC status will suffer from both problems of unobserved heterogeneity and sample selection. To address these challenges, I designed a novel survey and collected data on a set of 148 early stage high-tech start-ups. By analyzing the set of multiple financing offers—both those taken and declined—made to start-ups in this sample, I identify characteristics of the VC firm (proxies for prominence) which “explain” the variation in price offered to acquire start-up equity at a point in time, holding characteristics of the start-up fixed. Using this approach, I am able to estimate the marginal rate of substitution between price for affiliation and prominence of the certifying agent.

The empirical results confirm the main hypothesis that entrepreneurs are willing to forgo offers with higher pre-money valuations in order to access the equity of more prominent venture capitalists. The results are robust to (1) ordinal and cardinal measures of VC prominence (2) controls for tangible resource transfers from VC to start-up, and (3) different specifications of functional form. Moreover, the estimated effects are economically important. For example, the estimates suggest that a doubling of a VC firm’s deal experience in the start-up’s industrial segment is associated with a six to nineteen percent reduction in price offered to acquire start-up equity.
The remainder of this paper is organized as follows: section 2.2 explores the certification and status literature and derives a hypothesis about the relationship between VC prominence and price for start-up equity. Section 2.3 describes the methodology and data used to test this hypothesis. Empirical results are discussed in section 2.4, while a final section concludes with a discussion of implications and limitations of the study.

2.2 Theory and Literature

This section starts with a discussion of status as an economic good, develops the notion of a market for status acquisition, and then concludes with a hypothesis of the price to acquire status in the setting of early stage high tech start-ups acquiring financial capital from venture capitalists.

2.2.1 Status as an Economic and Positional Good

Reputation, which results from prior performance, has been identified as an economically important asset that can generate future rents when information among actors is asymmetric (Shapiro, 1983; Wilson, 1985). Similarly, social status, which depends on the prominence of its exchange partners and the extent of its relations with other actors in the system (Knoke and Burt, 1983) has also been associated with performance benefits, both for the possessor of status (Podolny, 1993) and its affiliates (Stuart, Hoang, and Hybels, 1999). While researchers have drawn a distinction between an actor’s reputation and its social status, (e.g., Podolny, 1993), the two concepts are likely endogenously determined. Two distinctions between status and reputation are worth mentioning, however. First, though reputation is regarded as a signal of future quality, the linkage between quality and status may be

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2 If reputation depends on an organization’s past performance and social status depends on the prominence or visibility of its affiliates, each of reputation and social status will likely be determined by the other. For example, an organization may obtain high status affiliates by building a reputation for high performance (and vice versa).
looser because status is *perceptually*-based (Podolny, 1993). Second, an important element of status is its *positional* nature, meaning that the value of status depends on its (perceived or actual) exclusiveness (Frank, 1985). By construction, therefore, not all items in a class of goods can be considered high status.

Because the supply of status is inherently constrained, economists have started to explore the consequent demand for status. For example, Frank (1984) attributes the compressed wage distribution relative to workers’ marginal products (within firms) to the demand for local status. Bagwell and Bernheim (1996) present a theory of “Veblen” effects (Veblen, 1899) in which people engage in conspicuous consumption because material displays of relative wealth signal status. This phenomenon may also help explain the demand for fashion goods (Coelho and McClure, 1993). For my purpose of examining the market for affiliation with prominent actors, however, the distinction between reputation and social status is not critical. For expository ease, I generally use the terminology “prominence” or “status” throughout the paper.

Regardless of the precise definition of status, producers of such goods appear to be in an enviable position: for goods of a given quality, increases in its status boost revenues for the producer due to enhanced consumer willingness to pay. Higher status also lowers the cost of producing and selling a good through, *inter alia*, perceptions of quality (Podolny, 1993). The positional nature of status goods therefore confers economic benefits to their producers. Indeed, several studies in the empirical literature have confirmed the effects of founders’ social status and connectedness on start-up performance (Burton, Sørensen, and Beckman, 1998; Shane and Khurana, 2000; Shane and Stuart, 2001).

Not only does status aid producers themselves in rent extraction, performance benefits can be realized by the producer’s *affiliates* through a process of legitimization and inter-organizational status transfer (Baum and Oliver 1991; Stuart, Hoang, and Hybels, 1999; Zuckerman, 1999). This phenomenon has also been examined in the context of reputable investment banks and venture capitalists
certifying the pricing of initial public offerings (Beatty and Ritter, 1986; Megginson and Weiss, 1991). These latter studies from the financial economics literature find that reputable agents, as a result of repeated interactions with the public markets, can credibly stake their reputations on the claim that the IPOs they back are not overpriced.

More generally, for a certifying agent to be effective, it must fulfill three conditions: (1) the certifying agent must have reputational capital at stake which would be compromised with an invalid certification; (2) the certifying agent’s reputational capital must exceed the largest one time wealth transfer from a mis-certification; and (3) the certified target must face a cost of leasing the reputational capital of the certifying agent (Booth and Smith, 1986; Megginson and Weiss, 1991). This final condition is an important one for insuring that the certifying agent would have the proper incentives to invest in its reputation. Unfortunately, it has not received much (if any) empirical attention; consequently it is this market for “leasing” reputational capital (and the associated prices for doing so) that forms the core of the empirical analysis in this paper.

2.2.2 Application: Pricing of Venture Capital
In order to empirically study a market for status acquisition, we will need an empirical setting in which there is heterogeneity in both the demand-for and supply-of affiliation with prominent organizations. As well, we will need data about the associated prices. Venture capitalists meet the three previously stated criteria of certifying agents (Megginson and Weiss, 1991) and can therefore be suppliers of certification.\footnote{Researchers have also documented other economic benefits to status, such as being less likely to be preyed upon as entrants (Podolny and Scott Morton, 1999).} Start-ups, especially those in the early stages, are often without the benefits of reputation and status, and may therefore demand certification. In this

\footnote{Like investment banks which bring multiple companies to the public market, VCs deal repeatedly with actors such as (institutional) investors, entrepreneurs, and organizations associated with exiting an investment (acquiring firms or investment bankers). Consequently, VCs acquire reputational capital based on past behavior and performance. In contrast, individual start-ups do not have repeated interactions with these actors, and do not build a reputation in this community.}
market for affiliation, the supply of financial capital (and attention) from prominent venture capitalists is limited, making affiliation with them a positional good. Furthermore, there is heterogeneity in demand for such association because entrepreneurs will have both different initial endowments of resources and status, as well as different expectations of the marginal benefit of affiliation. The market for acquiring prominence and experience will be reflected in prices offered by VCs and accepted by entrepreneurs in the exchange of start-up equity for venture capital. Furthermore, the price that VCs pay to access the equity of start-ups is important to both entrepreneurs and VCs. For entrepreneurs, the pre-money valuation they receive at a given round of financing determines how much equity is sold for the round of capital infusion, and may have corporate control implications. Venture capitalists also care about price. In a liquidity event, VCs earn the difference between the share-price at that time and the price they paid to acquire the start-up’s equity. Differences in price offered for equity in a given start-up by disparate VCs reflect expected benefits of association, a phenomenon to which Megginson and Weiss (1991: 883) allude: “...one of the services that entrepreneurial firms purchase with VC funding is easier access to capital markets and the ability of venture capitalists to reduce asymmetrical information in the offering process” (emphasis added). Left unanswered, however, is the purchase price start-ups pay to access high status VCs. The remainder of this section therefore addresses two areas central to designing an empirical study of venture pricing and the market for status acquisition: (1) why study early stage start-ups? and (2) what makes a VC prominent?

2.2.2.1 Why Study Early Stage Start-ups?

5 Consider the following thought experiment on whether financial capital from VCs should be considered a positional good: would entrepreneurs pay a premium for the capital from a VC firm if everyone were able to access that VC’s capital? In this situation, the financial capital would not necessarily be accompanied by VC attention (Ocasio, 1997) to developing the start-up, so entrepreneurs would be unlikely to pay a premium for affiliation with the VC.

6 Pre-money valuation is the product of the number of shares outstanding before the financing round and the per unit share price.
In order to study the market for affiliation, a departure from the usual empirical setting for studying third party certifications is necessary. Researchers in financial economics, whose primary interest has been on designing contractual and institutional mechanisms to solve information asymmetry problems, have concentrated on the IPO event to evaluate whether VCs (like investment banks [Carter and Manaster, 1990]) can use their reputation to certify that a new issue is correctly priced (Megginson and Weiss, 1991). These studies start from the premise that certification agents signal the true quality of an unknown (to the public market) firm, a potentially plausible assumption at the time of IPO. However, in situations in which the underlying quality is characterized by fundamental market or technical uncertainty (Knight, 1921; Branscomb and Auerswald, 2001), as is likely to be the case for early-stage start-ups, the problem is not conveying asymmetric information to investors. Instead, the entity in need of certification typically faces the situation of signaling quality through association with a prominent partner. In accord with this conceptual distinction, I examine an empirical setting in which there should be an active market for affiliation, the first professional round of financing for early stage high-tech entrepreneurs.

Analyzing early stage financing rounds is also interesting because decisions-made and structures-established in the early stage of start-ups are critical in shaping new enterprise development efforts important for their long term viability (Roberts, 1991; Baron, Burton and Hannan, 1999; Hellman and Puri 2000, 2001). Indeed, the compounding effect of negative events, any one of which could cause fledgling start-ups to fail, makes the risk of failure particularly high at this stage (Venture Economics, 1988a). Not only do new organizations face a “liability of newness” (Stinchcombe, 1965), choices start-ups make on business policies—both explicitly and implicitly—are imprinted early in the life of the organization (Baron, Burton and Hannan, 1999). Later rounds of financing are usually associated with less start-up uncertainty, and existing investors can weigh heavily in shaping the identity of subsequent investors (often through referrals or by virtue of their reputation).
Therefore, studying the status effects of venture capitalists on new enterprise development and innovation may be best done in the context of early stage start-ups (Roberts, 1991; Kortum and Lerner, 2000).

Finally, because conventional valuation methods are difficult to apply to young firms with intangible assets (Kaplan and Strömberg, 2000a; Smith and Smith, 2000), valuations of early stage start-ups are subject to a great deal of negotiation (rather than straightforward calculation). The resulting heterogeneity in prices for association with disparate VCs (which themselves vary in prominence and experience) is an important feature of early stage funding rounds that will help identify the market for status affiliation.

2.2.2.2 What Makes VCs Prominent?

The business press and descriptive literature have characterized simple monetary capital infusion as commodity-like in the start up process, and VCs have sought to differentiate themselves by the quality of business services and reputational capital they bring to their portfolio companies (e.g., New York Times, 2000; Timmons and Sapienza, 2000). VCs argue that while start-ups might give up a larger equity stake in their company for a given capital infusion by a more experienced VC, the entrepreneur's remaining stake in his company will be more valuable in the future as a result of affiliation with the venture capitalist's value-added services such as business referrals, a portfolio of complementary companies, and extensive mentoring. Entrepreneurs seem to accept this reasoning that there is value with being associated with experienced and connected VCs:

Venture funding is available from many sources. Entrepreneurs choose a lead venture partner to tap into practical experience, contacts, and reputations. 'The money is all the same,' says Louis Volpe, president of Arrowpoint Communications. 'But what type of additional value do you get? With Matrix Ventures, you get experienced people and a good network in telecom.' Those intangibles can make the difference in landing a key early customer, attracting top caliber employees, and lining up the best IPO underwriters. The experience can make a real difference driving a brand new company in the right direction fast.” (Boston Globe, 2000).
After a brief review of existing measures of VC prominence used in the extant literature and why they are inadequate for the study at hand, I discuss two straightforward concepts which contribute to VC prominence, namely VC industrial sector experience and IPO experience.

The financial economics literature has examined the certification hypothesis that reputable VCs can reduce underpricing\(^7\) of IPOs by using two measures of VC prominence. The first is simply venture backed versus non-venture backed issues (Megginson and Weiss, 1991), with a finding that IPOs backed by venture capitalists are associated with less underpricing. This set-up, however, implicitly treats VCs as one uniform class so that prominence differences among VCs are obscured. A second measure of VC prominence that has been used is the behavior of younger versus older VCs (a measure of existing reputation), with the results that (1) younger VCs have an incentive to rush their portfolio firms to the public markets to signal ability, and (2) more underpricing is associated with younger VCs (Gompers, 1996). These existing binary measures of VC reputation are too coarse, however, to capture the concept of how prominence differences among VCs relate to the market for affiliation by start-ups.\(^8\)

In addition, while the few studies of VC status in the organizational sociology literature have used finer-grained measures, i.e., centrality scores calculated from VC syndication networks (e.g., Podolny, 1999), interpreting these measures can be difficult due to both the multifaceted rationale for VC syndication (Lerner, 1994) as well as to the absence of a complete network for analysis. Instead, I utilize straightforward VC prominence concepts and measures as also used by Sorenson and Stuart (2001), VC industrial investment experience and IPO experience.\(^9\) I discuss

\(^7\) When an issue is underpriced, the newly-floating firm sacrifices value, which is captured by purchasers of the IPO, and can therefore be considered as a performance measure.

\(^8\) While Barry et al. (1990) use more nuanced measures, they interpret them in a monitoring context.

\(^9\) Note that Stuart, Hoang, and Hybels (1999) do not explicitly control for the prominence of venture capital firms in their sample because they do not have their identities.
each in turn since my interpretation of these concepts is slightly different than that given in the existing literature.

**VC Industrial Experience.** A keiretsu in the original Japanese organizational structure is a grouping of companies through historical association and equity and/or director interlocks such that each company maintains its operational independence but has permanent supply relationships with the others. As a result of this organizational structure, member companies are thought to be advantaged from a performance standpoint from enhanced information flow achieved at lower cost (Gerlach, 1992). In addition, intra-group competition is softened because member companies are often selected so that they do not overlap in function.

Kleiner Perkins, a prominent venture capital firm, claims to offer a *keiretsu* effect based on its network of portfolio companies and the potential cooperative opportunities as a result of information flows among them. As evidence, the firm claims that there are over 100 strategic alliances among its portfolio companies. Presumably, this has resulted because Kleiner Perkins has encouraged its businesses to conduct business among themselves, and acts as a source of introductions between organizations which could benefit from cooperation.

If true, the keiretsu effect implies that being associated with Kleiner Perkins will facilitate value enhancing inter-organizational relationships. Indeed, the firm's web site notes:

We borrow the term "keiretsu" from Japan's powerful networks of companies. However, unlike Japan, Kleiner's keiretsu is a particularly western, entrepreneurial, loosely-coupled web of relationships. Kleiner doesn't control any ventures: they're each independent, run by strong, outstanding entrepreneurs. There's no central controlling bank, or interlocking board of directors. But the executives in the KPCB Keiretsu often share experiences, insight, knowledge and information. This network, comprised of more than 175 companies and thousands of executives, has proven to be an invaluable tool to entrepreneurs in both emerging and developing companies.
As a venture capitalist gains more investment experience in a particular industrial sector, he or she will be more likely to acquire expertise needed to help start-ups in their portfolio acquire the resources for successful development. Each additional investment extends the VC’s information network, either acquiring important social contacts and/or gaining experience in effectively structuring deals or monitoring entrepreneurs in the industrial sector (Sorenson and Stuart, 2001). The probability of filling a “structural hole” (Burt, 1992) should therefore be increasing in this industry deal experience.

The VC information brokerage role can be particularly important to start-up development since private start-ups face imperfect markets for information (Aldrich and Zimmer, 1986; Aoki, 2000). These thin markets for information result both because start-ups are secretive in order to protect their competitive position, and because there may be few alternate channels outside of a trusted third party VC for information dissemination.

The VC information brokerage role may assist a start-up in business development in different ways depending on the stage of the enterprise. In the earlier stages, VCs may help in recruiting senior executive officers (Gorman and Sahlman, 1989; Hellman and Puri, 2001) and striking strategic alliances (Stuart, Hoang, and Hybels, 1999). In the start-up’s later stages, VCs may help assemble additional funds and/or achieve liquidity. This may be done through hiring talented investment bankers (Barry, et al., 1990; Megginson and Weiss, 1991) or in locating merger or acquisition partners (Hsu, 2000). Because these resources are reinforced by the venture capitalist’s investment experience in the start-up’s industrial sector, entrepreneurial demand for VC affiliation should be increasing in the VC’s industry deal experience.

**VC IPO Experience.** VC firms with IPO experience give entrepreneurs additional information beyond merely the VC’s investment experience—it is a
measure of what has been traditionally regarded as a highly successful outcome.\textsuperscript{10} For example, an often-cited Venture Economics (1988b) study reports that the most profitable exit for a VC is an IPO. This study found that a $1 investment in a firm that goes public provides an average cash return of $1.95 in excess of the initial investment (on an average holding period of 4.2 years). In contrast, an investment in an acquired firm yields a cash return of $0.40 over a 3.7 year holding period. While somewhat dated, the Venture Economics study provides a basis for examining a VC’s IPO experience as an element of its prominence and reputation.

A VC’s IPO experience is probably also correlated with its relations with investment bankers. For example, Bygrave and Timmons (1992) found that high status VCs tend to maintain close relationships with high status investment banks. Furthermore, Megginson and Weiss (1991) found that entrepreneurs will be attracted to VC funds which are perceived to have tight relationships with prominent underwriters. Consequently, entrepreneurial demand for VC affiliation should be increasing in the VC’s IPO experience.

Finally, one may wonder why prices charged by competing VCs – even those with extensive industrial deal or IPO experience – to acquire the equity in a given start-up can be differentiated in equilibrium. VCs with higher prominence may be able to sustain their higher prices (rather than having competition erode the prices they receive) as a result of status being a positional good. Consequently, while financial capital \textit{per se} is not a differentiated good, the status of venture capitalists providing the financial capital (and resulting inter-organizational transfer of status effects) can be a source of sustained differentiation among VC organizations. This helps resolve the empirical puzzle that entrepreneurs are willing to pay a premium for seemingly functionally equivalent financial capital from some VCs.

The main hypothesis to be tested is therefore: \textit{The price that entrepreneurs pay in the market for affiliation is inversely associated with VC prominence.}

\textsuperscript{10} For this reason and also because of its visibility, venture capital researchers have widely used the IPO event as a performance metric in both the organizational sociology (e.g., Stuart, Hoang and Hybels, 1999; Shane and Stuart, 2000) and finance (e.g., Barry, et al., 1990; Gompers and Lerner,
2.3 Methodology and Data

2.3.1 Methodology

To test this hypothesis I use a method drawn from Stem (2000) in collecting data on the bundle of offers made to start-ups for financing the first professional round. This methodology, by taking an offer as the unit of analysis, is well suited to studying the market for affiliation because examining multiple price observations associated with venture capitalists of varying prominence for a given start-up will in effect trace out a demand curve for affiliation.\textsuperscript{11} Consequently, the tradeoff between price and prominence can be estimated. In addition, by using a multiple offers method, I will be able to take into account start-up firm effects econometrically in explaining valuation differences across financing offers, thus mitigating the problem of unobserved heterogeneity. By holding start-up qualities fixed, we can turn our attention to VC experience and prominence to understand the variation in price paid to acquire start-up equity at a point in time.

This section describes both the details of the data collection process and the data used to test the key hypothesis. Before doing so, however, it will be useful to address two issues: (1) why a simple cross sectional analysis is inadequate, and (2) data collection challenges associated with employing the proposed methodology. The first issue is a methodological one for which there are two fundamental explanations for using a method more complex than simple cross-sectional analysis. First, there may be unobserved or mis-measured start-up qualities correlated with the price VCs pay for equity. Secondly, there may be an unobserved (to the econometrician) selection process whereby start-ups of a certain type are paired with VCs. Without

\textsuperscript{11} To my knowledge, the incidence of start-ups receiving multiple financing offers has only been investigated in one prior study. Smith (1999) reports 71\% of the responding companies in his survey received more than one financing offer, with 54\% receiving three or more offers, though there are (acknowledged) errors in his methodology making overestimation likely. While the rate of multiple offers is interesting in its own right, the current study instead uses multiple financing offer events to
detailed controls in the empirical analysis, cross-sectional estimates would likely be biased in a way sensitive to the sampling scheme.

To collect data on a start-up’s financing offers is a challenge in itself, since early-stage entrepreneurs are typically (and rightfully) reluctant to disclose information that might compromise their strategic position (Gompers and Lerner, 1999; Hellman and Puri, 2000). In addition, VC market consulting companies do not collect data on the bundle of financing offers received by start-ups. Consequently, obtaining the set of counterfactual financing offers (rather than assembling a matched comparable, for example) requires asking entrepreneurs themselves for the sensitive information. I do so through a survey instrument. While designing and administering the survey was a labor-intensive process, few substitutes exist to gather detailed information about (1) the founding and organization of the start-up, (2) the VCs offering to invest in the start-up, and (3) entrepreneurial perceptions of the VC’s status. A brief section describing institutional details about the sampled start-ups precedes a discussion about the data.

The MIT E-Lab Program. The MIT Entrepreneurship Program offers a semester-long class, “Entrepreneurship Laboratory” (“E-Lab”), which assembles teams of MIT and Harvard graduate students to study specific business-related issues at actual start-ups. In exchange for a complimentary business development analysis done by the graduate students, the senior executive officers of the start-up commit to allocating a certain amount of time and effort interacting with the students. E-Lab began in 1995 and approximately 300 start-up companies have applied to participate in the program. Far more companies apply for the program, however, than the supply of student teams.

In order to qualify for the program, the start-up has to meet two criteria: (1) its headcount must be less than approximately 35 at the time of entering E-Lab, and (2) it must have completed a Series A round of investment. This group of start-ups is an attractive one to survey for two reasons. First, the sample includes funded, early stage entrepreneurial choices in selecting investors.
start-ups which were not selected for any qualities related to the price that VCs paid to access their equity. Second, because of the MIT Entrepreneurship Program affiliation, they may be more inclined to participate in this research study.

Although this group of companies might be of higher “quality” relative to average start-ups (taking the decision to be involved with MIT to be a signal of quality), studying this sample for equity pricing would tend to bias the results against the effect I study. In particular, high quality entrepreneurs have their own reputations and established networks which would tend to obviate the need to pay a premium to access capital from more experienced funding sources. In any case, employing start-up fixed effects makes this quality issue unimportant for the purposes of the statistical analysis.

2.3.2 Data

Two types of data were collected. First, ordinal data (through a survey instrument) about the entrepreneur’s perceived ranking of each of the investors from which it received a financing offer were compared in each of the following dimensions: reputation, personal chemistry, professional contacts, and other business services. Second, more objective data about the VC’s investment experience (e.g., number of firms backed, funds raised, firms taken public, investments in each high-tech industrial segment) were collected from the Venture Economics database.¹²

After pre-testing the survey with entrepreneurs (both those contemporaneously going through the Series A financing process and those who had already gone through it), VCs, academics, and intellectual property attorneys, I mailed the survey to the population of approximately 300 E-Lab companies. I then placed telephone calls to follow-up with non-respondents. Most of the data were collected over the phone in the five months starting July 15, 2000. Respondents to the survey were typically a founder and/or a person who knew the details of the firm’s

¹² If a start-up’s Series A round was syndicated, I used information from the lead VC because prior research suggests that lead investors devote more direct resources to assisting their portfolio companies relative to syndication partners (Gorman and Sahlman, 1989).
start-up and financing history (frequently one of the following senior executive officers: CEO, CTO, and/or CFO).

Nearly half of the companies in the E-Lab population responded to the survey. These responses resulted in identifying a total of 246 offers to 149 start-ups. While 98 of these start-ups received a single financing offer, 51 of them received more than one offer for financing their first professional round. The average start-up receiving multiple offers averaged almost three offers each, resulting in 148 offers made to this set of companies.

Non-respondents seemed randomly mixed between those without time to participate in the survey and those (to a lesser extent) unwilling to participate in the study. Formal tests of differences between observables on the two samples are difficult, however, due to the data constraints on the firms not in the sample. Indeed, many of the firms in the E-Lab population are not yet listed in databases of venture capital industry consulting firms.

The representativeness of the E-Lab start-ups receiving multiple offers can be compared to those E-Lab companies receiving single offers, however. T-tests reveal that the observable characteristics of the start-ups and the VC firms from which they received offers are the same (statistically) on many dimensions. Specifically, many of the start-ups' qualities were the same between the groups: founding year, geographic location, number of employees (prior to the Series A funding), and corporate ownership held by the founding team. In addition, many characteristics of the VCs funding the start-ups were the same: age, geographic location, number of IPOs, number of prior funds raised, and industrial deal experience. The multiple- and single-offer firms differ, however, in the amount raised and the pre-money valuation in the Series A round, as well as in the cumulative external funds raised by the time of the survey. In order to use the fixed effects methodology, only the set of firms receiving multiple financing offers is analyzed in this paper, though comparisons to cross sectional results will also be made in the empirical analysis.
**Descriptive Statistics.** The mean price VCs initially offered to access start-up equity was $288 thousand dollars per percentage stake. Based on these data, the average portfolio start-up had a pre-money valuation offer of $20.6M (with a standard deviation of $32.9M) at the first professional round. Note that several of the companies had prior informal rounds—such as “angel” and/or “friends and family” rounds before their first VC round. In addition, the average company in this data set was funded in the late 1990s, a period when inflows to the VC sector may have inflated start-up valuations relative to other time periods (Gompers and Lerner, 2000). Finally, start-up offers given to start-ups with multiple offers averaged $11.7M *more* in pre-money valuation relative to their single-offer counterparts, a difference which is statistically significant.

As summarized in Table 2.1, the key independent variables are correlates of VC status and reputation.\(^\text{13}\) Several of these measures are ordinal rankings, including REPUTATION RANK and MENTORING RANK. For each of the VC offers they received, survey respondents were asked to *comparatively rank* the VCs on these (and related) dimensions associated with extra-financial business services provided by the VC (a copy of the survey is found in Appendix 2A). A second set of VC experience measures are based on cardinal data derived from the Venture Economics database. These include, for example, VC INDUSTRIAL DEAL EXPERIENCE and VC IPO EXPERIENCE. A pairwise correlation matrix of these variables is found in Table 2.2.

The average VC in the sample was 13.4 years old and had raised just under eight funds. On average, the VC companies in this sample took nearly 17 companies public, a figure reflected in the VC IPO EXPERIENCE variable. VCs in this sample had backed, on average, 28 firms in the target portfolio company’s industrial sector. The industrial representation of the underlying start-ups in the sample is fairly typical of the broader set of industries funded by venture capital over the same time period. 29% of the sampled companies are in Internet services, 24% are in Internet infrastructure, with almost 59% of the overall sample in the Internet sector. The
software sector makes up about 16% of the sample, while communications and health sciences each comprise 10% of the sample, respectively. This seems to mirror the overall financing trends in the venture capital sector over the past four years (the average company in the sample was founded in the middle of 1997). For example, according to Venture Economics, in 1999, 40% of VC disbursements went to Internet-based start-ups, while 57% of VC funds in the first three quarters of 2000 were invested in the sector.

2.3.3 Regression Model

Testing the key hypothesis developed in the previous section involves using ordinary least squares (OLS) regressions of PRE-MONEY RANK and PRICE PER EQUITY UNIT on the ordinal and cardinal measures of VC prominence. The choice of functional form for the regression analyses, however, is not straightforward. While there seems to be little theoretical guidance on the functional form for hedonic regressions (Berndt, 1991), the type most appropriate to analyzing my data, a Box-Cox transformation suggests that the dependent variable should be specified in log form, with mixed results for the functional form for the independent variables. In the empirical analysis on cardinal data, I follow Gompers and Lerner (2000) in using a “log-log” framework because the distribution of most of the covariate measures of VC reputation is skewed. The empirical results are also robust to a “log-linear” functional form, a result that will be discussed in the next section.

For start-up $i$ receiving offer $j$ the general form of the empirical model is:

$$P_{i,j} = \beta'X_{i,j} + \alpha_i + \delta_j + \mu_{i,j},$$

where $P_{i,j}$ represents the price per equity unit the VC offers to acquire the start-up’s equity. Let $\epsilon_{i,j} = \alpha_i + \delta_j + \mu_{i,j}$ where $\alpha_i$ captures start-up invariant effects, $\delta_j$ represents VC offer invariant effects, and $\mu_{i,j}$ is an error term not correlated with $X_{i,j}$, a vector of VC-related covariates. As is conventionally

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13 An interesting covariate would have been the internal rate of return data on a VC firm’s previous funds, but this information is usually held confidential by VC firms (Gompers and Lerner, 1999).
the case, I assume that \( \epsilon_{i,j} \) is homoskedastic and that \( \mu_{i,j} \) is independently and identically distributed, but that \( E(\alpha_i, \delta_j | X_{i,j}) \neq 0 \). By introducing a set of start-up firm fixed effects, \( D \), one for each of the \( N \) start-ups in the sample, OLS estimation on the following expression satisfies the Gauss-Markov conditions (Greene, 1997):

\[
\ln P_{i,j} = \ln \beta' X_{i,j} + \phi_1 D_1^j + \ldots + \phi_N D_N^j + \mu_{i,j}
\]

where \( D_k^i = 1 \) if \( k = i \) for \( k = 1 \ldots N \) and zero otherwise.\(^{14}\) This is the basic estimating equation used in the empirical analysis.

2.4 Empirical Results

The empirical assignment is straightforward; it is to test the hypothesized negative relationship between the price VCs offer for start-up equity and correlates of VC prominence. This section is therefore organized around three empirical tables which demonstrate this relationship and its robustness to different measures of the key variables. The analysis begins in Table 2.3, which reports start-up fixed effects OLS regressions of the PRE-MONEY VALUATION RANK of financing offers as the dependent variable.\(^{15}\) This dependent variable, as is the case with another ordinal variable used in the analysis, REPUTATION RANK, is based on entrepreneurs’ ordering of the set of offers they received, with higher values reflecting worse outcomes. The first column, (2.3-1), shows a simple bivariate negative correlation between these two ordinal variables. The next column demonstrates a similar effect when an alternate measure of VC prominence, VC INDUSTRIAL REPUTATION LIKERT, is used. This variable is a rating made by entrepreneurs, on a one to five scale (five being a high response), of their perception of a VC’s reputation in the

\(^{14}\) In some specifications in the empirical analysis, VC dummies for VCs which enter the dataset at least three times are included. Eight VC firms in the sample fulfill this criterion.
start-up's industrial sector. Together, these bivariate correlations suggest that entrepreneurs perceive trade-offs between pre-money valuation and VC prominence. Asking respondents *ex-post* about their ranked evaluation of venture capitalists, however, may induce recall bias and/or rationalization of their choice of VC, believing (even if not “true”) that they made the “right” investor choice.

As an (imperfect) way to control for these potential biases (which are inherent in these types of survey data), I introduce OFFER TAKEN DUMMY, an indicator variable taking a value of one if the entrepreneur selected the offer.\(^\text{16}\) (2.3-3) shows that REPUTATION RANK is robust to OFFER TAKEN DUMMY, indicating that the result is not being driven by rationalization of entrepreneurs of their chosen investors, the most likely candidate for recall bias.

(2.3-4) adds an additional measure of VC prominence, VC INDUSTRIAL DEAL EXPERIENCE, a count of the VC's prior deals in the target start-up's industrial segment. As well, this regression introduces two important controls also employed in much of the remainder of the empirical analysis: VC FUNDS and VC AGE. VC FUNDS, the number of funds the VC has raised, is an important measure of a VC’s “liquidity” available for start-up investment (Gompers and Lerner, 1999). VC AGE is the difference in years between the VC's and start-up's foundings. Not only may VC AGE impart different incentives to the venture capitalists (Gompers, 1996), age may also be correlated with differential organizational learning effects (Hannan, 1998; Sørensen and Stuart, 2000). The estimates indicate that both REPUTATION RANK and the newly introduced independent VC status measure, VC INDUSTRIAL DEAL EXPERIENCE, are statistically significant. Moreover, the results are economically significant with a doubling of REPUTATION RANK and

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\(^\text{15}\) A comparison with an analysis that might be done for cross sectional data is not presented (e.g., without start-up firm fixed effects) because PRE-MONEY VALUATION RANK would not be applicable.

\(^\text{16}\) I also tried using the average of entrepreneur rankings of VC j by all entrepreneurs receiving an offer from j, excluding the ranking by start-up k itself, to control for entrepreneurial recall bias. This effort was not successful, however, due to the lack of multiple observations for many VCs in the dataset. This was unfortunate since this variable could have been a good instrument for VC prominence if prominence and price are endogenously determined.
VC INDUSTRIAL DEAL EXPERIENCE associated with about a 33% decrease and 52% increase, respectively, in offered PRE-MONEY VALUATION RANK. Finally, one may believe that these results are being driven by entrepreneurs willing to pay a premium to be affiliated with a handful of VCs that appear in the data set. In (2.3-5), I include a set of eight VC dummy variables corresponding to VCs which enter the data set at least three times, as well as one VC location dummy each for Massachusetts and California. The statistical significance of REPUTATION RANK is robust to inclusion of these VC dummy variables. Taken together, Table 2.3 supports the hypothesis that entrepreneurs pay to affiliate with more prominent and experienced VCs. Due to the ordinal quality of offered PRE-MONEY VALUATION RANK, however, OLS regression may not be an adequate estimation method since all available information about the ordered responses is not used.17

For this reason, the remaining empirical analysis employs offered PRICE PER EQUITY UNIT as the dependent variable. Table 2.4 starts with an important comparison between two specifications relating PRICE to VC INDUSTRIAL DEAL EXPERIENCE. The first estimation, (2.4-1), is done as if one were doing a cross sectional study of accepted financing offers across all start-ups in the E-Lab sample—both those receiving single and multiple financing offers. In contrast, (2.4-2) restricts the sample to those start-ups receiving multiple offers and includes start-up firm fixed effects. The results are striking, with the estimated coefficient on VC INDUSTRIAL DEAL EXPERIENCE over four times as large in magnitude and more precisely estimated in the latter specification. In addition to being statistically significant, the estimate in (2.4-2) implies that a doubling of VC industrial deal experience is associated with an 18.7% discount in acquiring start-up equity. The comparison between the first two specifications in Table 2.4 indicates the severity of potential unobserved heterogeneity and/or selection effects in estimating the effect of VC prominence on price.

17 The basic results hold, however, in a fixed effects conditional logit specification on a dichotomous dependent variable indicating a first-best ranking of pre-money valuation. To my knowledge, an estimation method for a multiple outcome ordered dependent variable with fixed effects is not
Two sets of controls are introduced in (2.4-3). The first is offered PRE-MONEY VALUE, which may be an important control variable because the dependent variable, offered PRICE PER EQUITY UNIT, can be thought of as a measure of post-money valuation, the product of the number of equity shares outstanding after the financing round and the price per share paid by the VC. In addition VC DUMMIES and VC LOCATION DUMMIES are included to control for potential VC effects. Even with these stringent controls, the key result on VC INDUSTRIAL DEAL EXPERIENCE is preserved, albeit at a reduced economic significance level. The negative relationship between VC prominence and PRICE PER EQUITY UNIT is also robust to an alternate measure of prominence, VC IPO EXPERIENCE, a count of the number of previous portfolio companies that a VC has taken public, a result demonstrated in (2.4-4). In addition, I ran a wide variety of robustness checks, including specifying log-linear models and using clustered standard errors to correct for data that are not independent within groups but are independent across them. In both cases, the core results hold (though at diminished statistical significance levels).

Finally, Table 2.5 addresses a specific issue: is it possible to separate the effects of VC prominence from other resources VCs may provide to their portfolio companies? The empirical strategy is to interact measures of VC prominence (VC INDUSTRIAL DEAL EXPERIENCE) with measures of direct resources to entrepreneurs (RECRUITING RANK and MENTORING RANK). The analysis once again begins by comparing the first two columns of the table. (2.5-1) is a specification analyzed as if the data were cross-sectional, and includes all accepted financing offers. None of the key variables are significant. In contrast, (2.5-2) uses start-up fixed effects on the set of multiple offers, and finds a significant interaction effect between VC INDUSTRIAL DEAL EXPERIENCE and RECRUITING RANK, which quantifies the bias of a cross-sectional technique. While the direct VC resource variable (RECRUITING RANK) is statistically significant, the measure of VC
prominence (VC INDUSTRIAL DEAL EXPERIENCE) is not. The interaction effect implies, however, that holding the resource measure constant, increases in VC prominence lead to a PRICE discount. This result is robust to inclusion of the control variable PRE-MONEY VALUE (2.5-3) and an alternate measure of VC resource, MENTORING RANK (2.5-4). These estimates should not be over-interpreted, however, because the empirical strategy is only imperfectly aligned with the underlying concept of separating VC status effects from VC resource transfer effects. Taken together, however, the empirical analyses provide evidence that entrepreneurs pay a premium to access capital from more prominent VC firms. This is consistent with Megginson and Weiss’ (1991: 882) observation that: “The investment in reputational capital by venture capitalists allows them to remain competitive in the venture capital industry as well as the capital markets.”

2.5 Discussion and Conclusions

I have tested and confirmed the proposition that entrepreneurs are willing to accept a discount on the valuation of their start-up in order to access the capital of venture capitalists with higher prominence. These results help deepen our understanding of the market for affiliation by presenting empirical evidence that affiliation is an ordinary economic good for which actors seeking association will face a price-prominence trade off. This finding is consistent with the view that venture capitalists’ experience, information network, and/or reputation may be more distinctive than their financial capital. These conclusions are drawn from an analysis of multiple offers to a set of start-ups, which allows a high degree of statistical control. Because the characteristics of the start-up can be held constant, only differences in VC prominence across financing offers explain inter-offer variation in price for start-up equity.

This study is not without limitations. First, the sample size is modest, with 148 offers. In addition, there are covenants in the term sheets associated with the multiple
financing offers for which I am not able to control. The price VCs initially offer for equity may not be the only factor that matters when entrepreneurs select a VC company, and other dimensions of the term sheet may not be "priced in" to the offered pre-money valuations.\textsuperscript{18} Unfortunately there is little finance theory to guide the discussion on this point. Some studies, however, have provided evidence of convergence in VC financing agreements as a result of using the same law firms (Suchman, 1995). As well, results from my survey (not reported in this paper) suggest that entrepreneurs are most worried about negotiating the highest possible pre-money valuation relative to other covenants in the term sheet.

Second, it might be important to make econometric corrections for potentially truncated opportunity sets of financing offers for some start-ups in the sense of getting only a limited draw of offers from the set of all possible VC firms. Without a more complete understanding the process generating financing offers, however, this adjustment is difficult.

Finally, this study does not test the ex-post performance implications of selecting a particular VC. The findings in the present study are consistent with the theory that entrepreneurs who are tied into more "connected" networks at top VC companies expect to come across more opportunities, but have to pay to access these networks. The expectation is that in an ex-post sense, accepting funding from a more connected financier, while not necessarily getting the lowest cost of capital, is going to increase the value of the firm faster than having gone with a less connected financier. The explicit performance implications of accessing stronger networks, however, are left unresolved. For example, did start-ups accepting funding from more reputable VCs receive higher step-ups in valuation in subsequent rounds? Did they

\textsuperscript{18} Indeed, the price data I collect may not reflect the final offers that rival VCs would have been willing to pay following potential negotiation between entrepreneur and VC. However, obtaining such data on willingness to pay would be extremely difficult, if not impossible.
achieve an IPO faster or deliver products to the market more quickly? Researching these questions are fertile areas for future research.
# TABLE 2.1

**VARIABLES, DEFINITIONS AND DESCRIPTIVE STATISTICS**

<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>DEFINITION</th>
<th>MEAN</th>
<th>STD. DEV.</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DEPENDENT VARIABLES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE-MONEY VALUATION RANK</td>
<td>Ordinal rank (one being first best) of pre-money valuation associated with a VC financing offer compared to offers received from other VC firms.</td>
<td>1.905</td>
<td>1.006</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>PRICE PER EQUITY UNIT</td>
<td>Price offered by a VC for one percent of a start-up's equity (millions of dollars) at the first professional round of funding.</td>
<td>0.288</td>
<td>0.410</td>
<td>MIT Survey</td>
</tr>
<tr>
<td><strong>ORDINAL RANK VARIABLES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>REPUTATION RANK</td>
<td>Ordinal rank (one being first best) of the overall reputation, mentoring services, or recruiting services of the VC associated with a financing offer, as perceived by the entrepreneur. The comparison is made relative to other VC offers.</td>
<td>2.095</td>
<td>1.163</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>MENTORING RANK</td>
<td></td>
<td>2.081</td>
<td>1.152</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>RECRUITING RANK</td>
<td></td>
<td>2.054</td>
<td>1.165</td>
<td>MIT Survey</td>
</tr>
<tr>
<td><strong>VC FIRM CHARACTERISTICS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC INDUSTRIAL DEAL EXPERIENCE</td>
<td>Number of VC portfolio companies in a start-up firm's industrial segment.</td>
<td>28.038</td>
<td>26.636</td>
<td>Venture Economics</td>
</tr>
<tr>
<td>VC INDUSTRIAL REPUTATION LIKERT</td>
<td>Likert rating of a VC's industrial reputation, on a 1-5 scale, with higher values indicating better reputation.</td>
<td>3.466</td>
<td>1.362</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>VC FUNDS</td>
<td>Number of funds raised by the VC firm.</td>
<td>7.833</td>
<td>6.676</td>
<td>Venture Economics</td>
</tr>
<tr>
<td>VC IPO EXPERIENCE</td>
<td>Number of start-ups in the VC’s portfolio taken public.</td>
<td>16.600</td>
<td>23.516</td>
<td>Venture Economics</td>
</tr>
<tr>
<td>VC AGE</td>
<td>Number of years between VC firm formation and incorporation of the start-up.</td>
<td>13.364</td>
<td>10.863</td>
<td>MIT Survey, VE</td>
</tr>
<tr>
<td>VC LOCATION DUMMIES</td>
<td>Dummy = 1 if VC is located in Mass.</td>
<td>0.473</td>
<td>0.501</td>
<td>MIT Survey, VE</td>
</tr>
<tr>
<td></td>
<td>Dummy = 1 if VC is located in Calif.</td>
<td>0.162</td>
<td>0.370</td>
<td>MIT Survey</td>
</tr>
<tr>
<td><strong>CONTROLS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PRE-MONEY VALUE</td>
<td>The product of the price offered per share in the Series A financing round and the shares outstanding before the financing round.</td>
<td>20.589</td>
<td>32.935</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>OFFER TAKEN DUMMY</td>
<td>Dummy = 1 if the entrepreneur selected this offer to fund his start-up.</td>
<td>0.345</td>
<td>0.477</td>
<td>MIT Survey</td>
</tr>
</tbody>
</table>

* The natural logarithm of a variable, X, will be denoted L X
TABLE 2.2  
PAIRWISE CORRELATION MATRIX

<table>
<thead>
<tr>
<th></th>
<th>Reputation rank</th>
<th>Recruiting rank</th>
<th>Mentoring rank</th>
<th>Indust. Rep. Likert</th>
<th>VC industry deal exp.</th>
<th>VC IPO exp.</th>
<th>VC Funds</th>
<th>VC Age</th>
<th>Offer taken</th>
<th>Pre-money value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reputation rank</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Recruiting rank</td>
<td>0.70*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mentoring rank</td>
<td>0.64*</td>
<td>0.77*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indust. Rep. Likert</td>
<td>-0.36*</td>
<td>-0.24*</td>
<td>-0.19*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC ind. deal exp.</td>
<td>-0.04</td>
<td>-0.01</td>
<td>0.08</td>
<td>0.27*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC IPO experience</td>
<td>-0.02</td>
<td>0.00</td>
<td>0.11</td>
<td>0.23*</td>
<td>0.72*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC Funds</td>
<td>-0.05</td>
<td>-0.06</td>
<td>0.02</td>
<td>0.38*</td>
<td>0.72*</td>
<td>0.82*</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC Age</td>
<td>-0.05</td>
<td>0.05</td>
<td>0.06</td>
<td>0.38*</td>
<td>0.59*</td>
<td>0.64*</td>
<td>0.66*</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Offer taken</td>
<td>-0.43*</td>
<td>-0.40*</td>
<td>-0.45*</td>
<td>0.18*</td>
<td>0.03</td>
<td>0.06</td>
<td>0.03</td>
<td>-0.09</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Pre-money value</td>
<td>0.15</td>
<td>0.13</td>
<td>0.13</td>
<td>0.26*</td>
<td>0.15</td>
<td>0.11</td>
<td>0.22*</td>
<td>0.16</td>
<td>-0.06</td>
<td>1</td>
</tr>
</tbody>
</table>

* = significant at the 5% level
### TABLE 2.3
PREMONEY VALUATION RANK
START-UP FIXED-EFFECTS REGRESSIONS

<table>
<thead>
<tr>
<th>Dependent Variable = PRE-MONEY VALUATION RANK</th>
<th>(2.3-1) Bi-variate correlation with reputation rank</th>
<th>(2.3-2) Bi-variate correlation with industrial reputation rating</th>
<th>(2.3-3) (2.3-1) with control for offer taken</th>
<th>(2.3-4) (2.3-3) with additional measure of VC prominence and controls</th>
<th>(2.3-5) (2.3-4) with VC dummies</th>
</tr>
</thead>
<tbody>
<tr>
<td>REPUTATION RANK</td>
<td>-0.226 (0.083)</td>
<td>-0.289 (0.089)</td>
<td>-0.301 (0.115)</td>
<td>-0.256 (0.129)</td>
<td></td>
</tr>
<tr>
<td>VC INDUSTRIAL REPUTATION LIKERT</td>
<td></td>
<td>0.170 (0.087)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L VC INDUSTRIAL DEAL EXPERIENCE</td>
<td></td>
<td></td>
<td>0.356 (0.180)</td>
<td>0.438 (0.196)</td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L VC FUNDS</td>
<td></td>
<td></td>
<td>-0.401 (0.190)</td>
<td>-0.308 (0.208)</td>
<td></td>
</tr>
<tr>
<td>L VC AGE</td>
<td></td>
<td></td>
<td>-0.074 (0.185)</td>
<td>-0.225 (0.216)</td>
<td></td>
</tr>
<tr>
<td>OFFER TAKEN DUMMY</td>
<td></td>
<td></td>
<td>-0.336 (0.183)</td>
<td>-0.389 (0.225)</td>
<td>-0.384 (0.248)</td>
</tr>
<tr>
<td>VC DUMMIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YES (8)</td>
</tr>
<tr>
<td>VC LOCATION DUMMIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>YES (2)</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>2.379 (0.190)</td>
<td>1.316 (0.312)</td>
<td>2.626 (0.231)</td>
<td>2.575 (0.649)</td>
<td>2.463 (1.018)</td>
</tr>
</tbody>
</table>

Regression Statistics

- R-Squared: 0.404, 0.382, 0.424, 0.504, 0.551
- Prob > F: 0.008, 0.054, 0.005, 0.013, 0.185
- No. observations: 148, 148, 148, 120, 120

48
<table>
<thead>
<tr>
<th></th>
<th>(2.4-1) Bi-variate correlation with VC industrial deal experience without start-up fixed effects</th>
<th>(2.4-2) (2.4-1) with start-up fixed effects</th>
<th>(2.4-3) (2.4-2) with control for pre-money valuation and VC dummies</th>
<th>(2.4-4) (2.4-3) with alternate measure of VC prominence</th>
</tr>
</thead>
<tbody>
<tr>
<td>L VC INDUSTRIAL DEAL EXPERIENCE</td>
<td>-0.043 (0.113)</td>
<td>-0.187 (0.054)</td>
<td>-0.061 (0.028)</td>
<td>-0.051 (0.025)</td>
</tr>
<tr>
<td>L VC IPO EXPERIENCE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L VC FUNDS</td>
<td>0.001 (0.171)</td>
<td>0.119 (0.058)</td>
<td>0.026 (0.029)</td>
<td>0.031 (0.030)</td>
</tr>
<tr>
<td>L VC AGE</td>
<td>0.196 (0.140)</td>
<td>0.048 (0.056)</td>
<td>0.049 (0.030)</td>
<td>0.084 (0.039)</td>
</tr>
<tr>
<td>L PRE-MONEY VALUE</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC DUMMIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC LOCATION DUMMIES</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CONSTANT</td>
<td>2.319 (0.236)</td>
<td>3.161 (0.133)</td>
<td>0.661 (0.214)</td>
<td>0.372 (0.182)</td>
</tr>
<tr>
<td>Regression Statistics</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.037</td>
<td>0.382</td>
<td>0.991</td>
<td>0.992</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.297</td>
<td>0.054</td>
<td>0.000</td>
<td>0.000</td>
</tr>
<tr>
<td>No. observations</td>
<td>101</td>
<td>120</td>
<td>120</td>
<td>102</td>
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</table>
### TABLE 2.5  
VC RESOURCE AND PROMINENCE INTERACTION EFFECT  
START-UP FIXED-EFFECTS REGRESSIONS

<table>
<thead>
<tr>
<th></th>
<th>Dependent Variable = L PRICE PER EQUITY UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(2.5-1) Regression with VC prominence, VC resource, and interaction, without start-up fixed effects</td>
</tr>
<tr>
<td>L VC INDUSTRIAL DEAL EXPERIENCE</td>
<td>-0.217 (0.262)</td>
</tr>
<tr>
<td>RECRUITING RANK</td>
<td>-0.167 (0.665)</td>
</tr>
<tr>
<td>MENTORING RANK</td>
<td></td>
</tr>
<tr>
<td>Interaction Effects</td>
<td></td>
</tr>
<tr>
<td>VC IND DEAL EXP * RECRUITING RK</td>
<td>0.152 (0.221)</td>
</tr>
<tr>
<td>VC IND DEAL EXP * MENTORING RK</td>
<td></td>
</tr>
<tr>
<td>Controls</td>
<td></td>
</tr>
<tr>
<td>L VC FUNDS</td>
<td>0.001 (0.174)</td>
</tr>
<tr>
<td>L VC AGE</td>
<td>0.197 (0.140)</td>
</tr>
<tr>
<td>L PRE-MONEY VALUE</td>
<td></td>
</tr>
<tr>
<td>START-UP FIXED EFFECTS</td>
<td>YES (48)</td>
</tr>
<tr>
<td>CONSTANT</td>
<td><strong>2.504 (0.783)</strong></td>
</tr>
<tr>
<td>Regression Statistics</td>
<td></td>
</tr>
<tr>
<td>R-Squared</td>
<td>0.052</td>
</tr>
<tr>
<td>Prob &gt; F</td>
<td>0.402</td>
</tr>
<tr>
<td>No. observations</td>
<td>101</td>
</tr>
</tbody>
</table>
Appendix 2A.

**MIT Sloan Financing New High-Tech Ventures Survey**

Project Faculty: Edward Roberts, Michael Cusumano, Scott Stern, and Ken Morse  
Project Researcher: David Hsu

Summer 2000

We are undertaking a new research project with the goal of evaluating how entrepreneurs select potential investors to fund and help commercialize innovative technologies in the first professional round of financing a new venture, the Series A round.

Enclosed is a survey that we are administering to high-tech entrepreneurs from early stage ventures, which have negotiated and received Series A financing offers. This survey is designed to take *no more than 25 minutes to complete*, and is divided into three parts:

**Part 1** asks you questions about the general background of your company. **Part 2** asks you a brief set of questions for *each* of the financing offers that you received. **Part 3** asks you to *comparatively rank* the offers along a number of dimensions. We assume that you are either a founder of the company or are familiar with the Series A financing of your company.

In addition to this survey, we hope that you will be able to share with us your business plan (as it was written at the time of your Series A financing), including resumes of the founders of the firm.

We will be happy to share the completed analysis with you. Participation in this study is entirely voluntary and you may decline to answer any questions. The information you provide will be kept *strictly confidential*, and findings will be reported in the aggregate and without attribution. Given the sensitive nature of the term sheet(s) and business plan, we have enclosed a signed non-disclosure agreement to ensure confidentiality.

Please return this survey and accompanying documents in the enclosed business reply envelope, and direct inquiries to David Hsu, who is pursuing this project for his dissertation.

*Thank you for your participation!*

Edward B. Roberts  
David Sarnoff Professor of Management of Technology

David H. Hsu  
Ph.D. Candidate, MIT Sloan
A. Founding the Company

When was your company founded (month, year)? __________________________

When was your company incorporated (month, year)? _______________________

<table>
<thead>
<tr>
<th>Name of Founder</th>
<th>Current job title</th>
<th>Company</th>
<th>Reason for leaving (if applicable)</th>
<th># of prior start-ups founded</th>
<th>Name of prior start-ups</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

If the founding team previously started other companies, which category best describes the average approximate internal rate of return(s) on Series A investment for those previous venture(s)?

- [ ] < 0
- [ ] 0-10%
- [ ] 11-50%
- [ ] 51-100%
- [ ] 101-500%
- [ ] >500%

How many of those founded firm(s) were taken public? __________________

At the time of start-up, what did your founding team consider to be the company’s key competitive advantage? (select the most important two)

- [ ] Establishing a new market
- [ ] Establishing a new technology
- [ ] Recruiting superior personnel
- [ ] Establishing an advantageous cost position
- [ ] Superior positioning in the product niche
- [ ] Maintaining superior intellectual property
- [ ] Superior customer service & responsiveness
- [ ] Superior product quality / reliability
- [ ] Other: ____________________________
B. Employee Information

Number of Employees: at the time of raising Series A financing: _____ as of 7/1/00: _____

Current number of employees in each of the following functions:

<table>
<thead>
<tr>
<th>R&amp;D</th>
<th>Sales</th>
<th>Marketing</th>
<th>Manufacturing or Operations</th>
<th>General &amp; Admin.</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please indicate which of the senior executive officers below was on the founding team. If not on the founding team, please designate from what source the executive officer came. Please "x" out the position if it does not exist in your company, and draw lines connecting positions, if one person holds multiple positions.

<table>
<thead>
<tr>
<th>CEO</th>
<th>COO</th>
<th>CFO</th>
<th>CTO</th>
<th>VP, Marketing</th>
<th>VP, Sales</th>
<th>VP, Bus. Dev.</th>
<th>Other:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

On founding team

Or, contact through:

- Personal friend
- Classmate
- Co-worker
- Investor/financier
- Recruiter
- Advisor

C. Financing the Company

Did you have a completed business plan before getting your Series A funding? □ Yes  □ No

Time from completing the business plan to receiving your first financing offer: _____ months

Who were the participants in your company’s financing(s) to date? If a number of “angel investors” participated, please group them all as “Angels” in the Investor column. If applicable, please place an asterisk (*) next to the lead investor.

<table>
<thead>
<tr>
<th>Round</th>
<th>Date</th>
<th>Investor</th>
<th>Amount</th>
</tr>
</thead>
</table>

Total number of financing offers for the Series A round: _____
What is the current percentage of corporate ownership held by the following groups:

<table>
<thead>
<tr>
<th>Founders &amp; option pool</th>
<th>Employees &amp; option pool</th>
<th>Venture capitalists</th>
<th>&quot;Angel&quot; investors</th>
<th>Strategic investors</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
</tr>
</tbody>
</table>

For the Series A financing, which of the following areas were the subject of active negotiation between the parties?

<table>
<thead>
<tr>
<th>Area</th>
<th>Not active</th>
<th>Very active</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-money valuation</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Board representation</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Employee option pool</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Vesting schedules</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Liquidation rights</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Anti-dilution clauses</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Other (specify: ___________________ )</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

Why did you select the offer you chose?

---

**D. Building Corporate Governance**

Number of members of the Board of Directors: _____

How many directors are from: within the firm _____ outside the firm _____

Number of board members appointed by your investors: _____

Please rate the importance of the following functions of your investor-appointed directors:

<table>
<thead>
<tr>
<th>Function</th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oversight and monitoring of the company</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Source of advice and counsel to the company</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Source of external business contacts</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Recruiting and team building</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Market validation/prestige</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>

Do you have a board of advisors? □ Yes □ No

Please rate the importance of the following functions of your board of advisors, if you have one:

<table>
<thead>
<tr>
<th>Function</th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oversight and monitoring of the company</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Source of advice and counsel to the company</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Source of external business contacts</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Recruiting and team building</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
<tr>
<td>Market validation/prestige</td>
<td>N/A</td>
<td>1 2 3 4 5</td>
</tr>
</tbody>
</table>
E. Product, Technology, and Strategy

Which industrial classification best describes your company:

☐ Internet: Services  ☐ Internet: E-tailer  ☐ Internet: Infra.  ☐ Internet: Other
☐ Software  ☐ Medical Devices  ☐ Biotech  ☐ Communications
☐ Computer hardware  ☐ Other (specify: ______________________ )

Actual company revenues:
(Thousands of dollars)

Year 1 2 3 4 5

Actual corporate profits/losses:

Year 1 2 3 4 5

Number of: patent applications filed by your firm: ______ patents pending: ______ patents issued to your company: ______

Has your firm entered into any technology licensing deals?
☐ Yes: licensed out ☐ Yes: licensed in

If your firm has licensed-out, what were the terms? ☐ Exclusive ☐ Non-exclusive

Who were the licensees? ☐ Product market incumbents ☐ Product market entrants

Actual licensing revenues by yr:
(Thousands of dollars)

Year 1 2 3 4 5

Has your firm been acquired since its inception? ☐ Yes ☐ No
If so, by whom?

At the time of your Series A financing, please rate the importance of each of the following as obstacles to the commercial success of your enterprise:

<table>
<thead>
<tr>
<th></th>
<th>Not an obstacle</th>
<th>Very important obstacle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lack of brand name image</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Lack of distribution channels/sales force</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Lack of servicing resources</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
<tr>
<td>Lack of manufacturing capability</td>
<td>N/A 1 2 3 4 5</td>
<td></td>
</tr>
</tbody>
</table>

55
Part II: Financing Offer Characteristics

Please complete one record for each term sheet you received, copying this form as many times as needed. If possible, please also attach a copy of the term sheet received from each investor organization.

Name of Investor: ____________________________

Location (City/State): _______________________

How did you make initial contact with this investor?

☐ Sent an unsolicited business plan
☐ He/she was a personal contact
☐ Referred by an advisor or friend
☐ Other (specify: ____________________________ )

If you were referred to the investor through a friend or knew the investor directly, how did you come to know that person?

_________________________________________

Does this investor host a regular conference or formal networking event for top managers of its portfolio companies?  ☐ Yes  ☐ No

Does this investor have dedicated personnel to help its portfolio companies in the following areas:

Recruiting   ☐ Yes  ☐ No
Finance & accounting   ☐ Yes  ☐ No
Business development   ☐ Yes  ☐ No

Please rate this financing offer/investor along the following dimensions:

<table>
<thead>
<tr>
<th>Dimension</th>
<th>LOW</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall reputation of this investor</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Reputation in your industrial sector</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Expected availability to mentor the team</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>“Chemistry” with this investor</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Expected ability to recruit key managers</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Potential contacts with key customers or suppliers</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Potential contacts with investment banks</td>
<td>N/A</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

What pre-money valuation did this investor assign to your company at the Series A round? $_______ Million

What post-money valuation did this investor assign to your company at the Series A round? $_______ Million

Proposed equity stake taken by this investor as a result of this financing offer: ______%
### Part III: Financing Offer Comparison Table

<table>
<thead>
<tr>
<th>Name of Financing Entity</th>
<th>Pre-Money Valuation</th>
<th>Overall Reputation of investor</th>
<th>Reputation of investor in your industrial sector</th>
<th>&quot;Chemistry&quot; with this investor</th>
<th>Mentoring</th>
<th>Contacts with key customers or suppliers</th>
<th>Recruiting managers and employees</th>
<th>Raising additional financing</th>
<th>Connections to professional services, e.g. investment banks</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABC Vultures</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>FFAF Funds</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Complex Angels</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

**EXAMPLE: Financing Offer Comparison**

**FINANCING OFFER COMPARISON RECORD**

Please place an asterisk (*) next to the offers you considered most carefully
Chapter Three

When Does Start-Up Innovation Spur the Gale of Creative Destruction?

(with Joshua Gans and Scott Stern)

3.1 Introduction

Over the past decade, there has been a rapid rise in the level of investment funding provided to technology-oriented start-up firms. Venture capital investments increased by more than an order of magnitude between 1991 and 1999 (VentureOne, 2000), and venture-backed firms currently account for more than 15% of all domestic industrial innovation (Kortum and Lerner, 2000). Not surprisingly, there is considerable interest in the economic implications of this surge in R&D investment in start-up firms (Gompers and Lerner, 1999; Kortum and Lerner, 2000; Hellman and Puri, 2000).

Many analysts suggest that start-up innovation impacs existing sources of market power by spurring the "gale of creative destruction" (Schumpeter, 1943; Christensen, 1997). However, industry studies suggest a more nuanced relationship (Gans and Stern, 2001). For example, in the biotechnology industry, cooperation between start-up innovators and more established firms is the norm (whether through licensing, strategic alliances or outright acquisition) (Orseniegio, 1989; Lerner and Merges, 1998). On the other hand, start-up innovators in the electronics industry often engage in creative destruction, earning their innovation rents through product market entry and competition with more established firms (Christensen, 1997). This paper attempts to understand these different patterns by evaluating how economic factors such as the strength of intellectual property protection shape the relative returns to cooperation versus competition.
Consider a cooperation strategy. Start-up innovators and more established firms share (at least) two distinct gains from trade in the "market for ideas": (1) preserving current market power and (2) avoiding duplicative commercialization investments, such as those associated with distribution, manufacturing, or a branded reputation. If an ideas market functions efficiently, incumbents can contract for innovations from start-ups (who then serve as technology suppliers) and so foreclose on a potentially important form of competition. Imperfections in the market for ideas, conversely, can spur a competitive strategy by start-up innovators.

We identify three key factors shaping start-up commercialization strategy. First, in the absence of completely enforceable intellectual property rights (IPR), start-up commercialization strategy will be responsive to the threat of expropriation (Arrow, 1962; Anton and Yao, 1994). The threat of expropriation is present whether a start-up competes or cooperates. Under competition, incumbent firms will attempt to reverse-engineer; in the context of cooperation, the start-up will likely disclose technical information to the established firm, weakening its bargaining position. Therefore, regardless of their commercialization strategy, an increase in the strength of IPR increases the absolute expected returns to start-up innovators. However, under cooperation, the overall (negotiated) returns to a start-up innovator reflects both the value of their proprietary knowledge as well as their ability to threaten the established firm with competitive entry. The combination of these two effects makes the payoffs to cooperation more sensitive to the strength of IPR than the payoffs to competition. Therefore, a given increase in the strength of IPR increases the relative returns to cooperation over competition.

Second, identifying and contracting with incumbents may involve substantial transaction costs. Even when IPR are well defined, there may be uncertainty about the value (or other characteristics) of the start-up technology; this uncertainty may necessitate detailed bargaining between the parties about royalty rates and other contingent contracting provisions (Arora, Fosfuri, and Gambardella, 1999). As such, bargaining intermediaries that substantially reduce the cost of forging an agreement
between the parties, such as venture capitalists or specialized legal counsel, may increase the relative likelihood of cooperation (Burt, 1992).

Finally, cooperation allows start-up innovators to exploit "complementary assets" controlled by incumbents, including distribution channels, regulatory or manufacturing expertise, and brand-name recognition (Teece, 1986). While avoiding duplication of sunk assets is important in some environments (such as when biotechnology firms exploit the regulatory expertise and distribution channels of established pharmaceutical companies), incumbent-owned assets confer minimal value in other settings (e.g., when start-ups develop incompatible technology). As the "cost" of product market entry increases, start-up innovators will be more likely to forego competition and earn their returns through the market for ideas.

This paper empirically evaluates whether commercialization strategy differs with measures capturing variation along these three dimensions – the strength of intellectual property, the cost of contracting, and the importance and effectiveness of complementary asset ownership. Perhaps surprisingly, little empirical work has been devoted to this topic. Most prior analyses of the relationship between start-up and established firms have tended to focus on the relative incentives to innovate in the first place, under the assumption that innovation by a start-up will be followed by product market competition with more established firms.¹ As well, several analyses have examined the form of cooperation between smaller research-oriented firms and larger established firms without considering the potential for product market entry.² By relating the choice between cooperation and competition to the firm’s economic environment, our analysis suggests that the competitive consequences of start-up innovation are endogenous to the commercialization environment. Specifically, the industrial organization consequences of the start-up financing boom depends on factors such as the strength of IPR and the availability of venture capital. In turn,

¹ The literature on R&D and product market competition between incumbents and start-up firms is too large to be summarized here. See Cohen and Levin (1989) or Gans and Sterr (2000a) for a review. ² See Salant, 1984; Katz and Shapiro, 1987; Pisano, 1990; Anton and Yao, 1995; Lerner and Merges, 1998.
these commercialization environment parameters depend, at least in part, on various aspects of public policy.

We report empirical results using a dataset composed of the commercialization strategies of 118 projects. We evaluate whether cooperation is associated with (a) innovations that receive formal IP protection (e.g., a patent), (b) firms with access to a network of contacts (e.g., through a relationship with a venture capitalist), and (c) environments where ownership of complementary assets by the start-up is perceived as ineffective in earning profits from innovation. We find that each factor is associated with a quantitatively significant effect on the probability of cooperation. For example, firms that possess IPR are estimated to be 23 percentage points more likely than non-patent-holders to pursue a cooperative strategy. While the impact of IPR is estimated relatively precisely, the estimates of the impact of venture capitalists and the costs of complementary assets are noisier (occasionally these factors are only significant at the 10% level). These core empirical findings are robust to the inclusion of a variety of controls, varying the definitions of each of our empirical concepts, and relying exclusively on within-industry or cross-industry variation. While we interpret this evidence cautiously given the small size of our sample and our imperfect measures of the concepts underlying the theoretical model, our findings do accord with a simple but novel model of strategic interaction between start-up innovators and incumbents in high-technology industries.

The remainder of this paper is organized as follows. The next section develops a simple model of start-up commercialization strategy. After a brief review of our data, the empirical results are presented in section four. A final section concludes.
3.2 A Simple Model of Start-Up Commercialization Strategy

This section presents a simple model identifying the key comparative statics associated with start-up commercialization strategy.\(^3\) Most notably, though an increase in IPR increases the absolute returns to both competition and cooperation, the fact that bargaining takes place in the “shadow” of potential product market competition raises the relative payoff to cooperation.

Consider a start-up innovator, \(E\), who has successfully developed a commercializable innovation.\(^4\) \(E\) faces a choice between entering the product market – the competitive strategy – or “selling” the innovation to an incumbent, \(I\) – the cooperative strategy. A cooperative strategy may be achieved through several mechanisms (from a licensing agreement to a strategic alliance to acquisition of \(E\) by \(I\)). While these mechanisms differ in how they impact future incentives to innovate and the locus of decision authority, they share a common feature: if an agreement is reached, \(I\) forecloses on product market competition with \(E\) and maintains monopoly profits. Monopoly profits are denoted \(\pi^m\), while \(E\) and \(I\) both earn \(\pi^c\) under the competitive strategy.

Under either strategy, commercialization involves sunk costs for the start-up firm. To compete in the product market, \(E\) must invest \(K\) in order to create the assets to produce, market and distribute its innovation. Undertaking the cooperative strategy also involves an upfront transaction cost, \(c\), associated with bargaining with \(I\) in the market for ideas. Since these costs are irreversible, \(E\) compares expected profits associated with each path in choosing its commercialization strategy.

---

\(^3\) While our model examines strategic interaction between a start-up innovator and a single incumbent, the underlying economic forces are more general. A more inclusive treatment would consider the possibility of non-exclusive cooperative behavior in the context of a pre-existing oligopoly (e.g., through non-exclusive licensing), distinguish more carefully between different types of cooperative strategies (e.g., between licensing, strategic alliances, or outright acquisition), and consider conduct between firms in the case of competition. Our approach simply highlights the key testable economic predictions for the commercialization choices of start-up innovators.

\(^4\) A commercializable innovation is one in which all technological uncertainty has been resolved (e.g., a prototype exists) and so, with (known) investments, the innovation could be introduced into the market.
Figure 3A illustrates the model. Note that regardless of which strategy it pursues, E faces a risk that I imitates the innovation. If E does choose to compete, I may imitate E’s innovation (i.e., “reverse-engineer”) with probability 1-\( p_r \), but, with probability \( \theta \), E successfully enforces its IPR. Therefore, with probability \((1-\theta)(1-p_r)\), I can commercialize an imitative technology. For simplicity, we assume that successful commercial imitation by I raises I’s profits by \( \Delta \) and reduces E’s by a similar amount, leaving industry profits unchanged.\(^5\) By choosing to compete, E earns expected profits of \( \pi^c - \Delta (1-p_r)(1-\theta) - K \), which are increasing in the strength of IPR (\( \theta \)).

Under the cooperative strategy, E’s return is determined through the outcome of a bargaining game with I. This bargaining game involves a potential “expropriation” hazard, since negotiating over the sale of an idea inevitably involves the risk of disclosure of that idea to the potential buyer, obviating the buyer’s willingness-to-pay (Arrow, 1962). To capture the expropriation risk, we assume that when E negotiates with I, I can imitate the innovation with probability 1-\( p_d \), but as in the competition setting, E can enforce its IPR with probability \( \theta \). For notational simplicity, we assume that \( \theta \) governs the strength of IPR under both the competition and cooperation strategies,\(^6\) and that the impact of expropriation by I is to increase its potential product market profits by \( \Delta \) and reduce E’s by a similar amount. As such, E faces a risk, with probability \((1-\theta)(1-p_d)\), that I commercializes an imitative technology in the event negotiations break down. In general, we expect (though do not require) \( p_d \) to be lower than \( p_r \): knowledge transfer during negotiations is more likely than reverse-engineering after commercialization by E.

\(^5\) Of course, expropriation may also change the level of industry profits. We are not aware of a complete treatment of how changes in product market rents arising from imitation impact optimal commercialization strategy. However, several models (available upon request) suggest that as long as imitation does not decrease total industry profits too much, our comparative statics are unchanged.

\(^6\) Our comparative statics hold as long as the probability of enforcement under each regime is impacted similarly by changes in factors such as the ease and scope of patent protection or the availability of legal remedies against IP infringement.
The possibility of expropriation impacts the expected outcome of negotiations between E and I. Allowing the bargaining outcome – that is, the transfer (τ) from I to E – to be determined by the Nash bargaining solution (as in Aghion and Tirole, 1994), each party “splits” the gains from trade. E’s profits in the absence of expropriation is equal to:

\[\tau - (\pi - \Delta(1 - p_r)(1 - \theta) - K) = \pi^m - \tau - \pi - \Delta(1 - p_r)(1 - \theta) \Rightarrow \tau = \frac{1}{2}(\pi^m - K) - \Delta(1 - p_r)(1 - \theta)\]

On the other hand, expropriation by I reduces the share of the monopoly profits E expects to receive. Expropriation by I does not entirely eliminate E’s rents since (a) E can still credibly threaten to reduce I’s profits by competing in the product market (Anton and Yao, 1994; 1995) and (b) E may be able to enforce its IPR with probability θ. However, relative to payoffs in the absence of expropriation, disclosure increases I’s potential competitive position (and similarly decreases E’s position). As such, using the same bargaining rule as above, E’s share under expropriation, \(\overline{\tau}\), will equate:

\[\overline{\tau} - (\pi - K - \Delta(1 - \theta)) = \pi^m - \overline{\tau} - (\pi - \Delta(1 - \theta)) \Rightarrow \overline{\tau} = \frac{1}{2}(\pi^m - K) - \Delta(1 - \theta)\]

Since E chooses to cooperate as long as

\[p_d \tau + (1 - p_d) \overline{\tau} - c \geq \pi^c - \Delta(1 - p_r)(1 - \theta) - K \Rightarrow \frac{1}{2} \pi^m - \Delta p_r (1 - p_d)(1 - \theta) - c \geq \pi - \frac{1}{2} K\]

E is more likely to choose cooperation as K rises, c falls, \(\theta\) rises or \(\Delta\) falls.

The comparative statics on K and c are not surprising. Cooperation is more likely when the sunk costs of product market entry are high relative to the costs of transacting with established firms. While K represents a “gain from trade” (avoiding duplicative investment in investments already owned by I), c represents a cost of trade with I. Our empirical work evaluates whether these costs of trade may be lower in the presence of third-party “brokers” (such as venture capitalists), who have long-

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\(^7\) This bargaining game can be enriched considerably to incorporate the strategic decision by the incumbent to invest in expropriation during the bargaining process with similar comparative statics for commercialization strategy (Gans and Stern, 2000a).
term reputations with incumbents and can therefore credibly certify the expected value of specific innovations.

The impact of a change in the strength of IPR is subtler. Increases in IP protection improve the start-up’s absolute returns to both the cooperative and competitive strategies. However, since the start-up’s bargaining outcome is equal to its absolute return under competition plus a fraction of the surplus associated with cooperation, an increase in the strength of IPR (through an increase in $\theta$ or a decrease in $\Delta$) increases the relative return to cooperation over competition. The probability of cooperation is increasing in the strength of IPR because the returns to cooperation depend on a bargaining process that internalizes $E$’s ability to threaten $I$ with competitive entry.

3.3 Data

The remainder of the paper evaluates the empirical salience of the predictions of this model. Our approach is straightforward (as in the spirit of Mansfield, Schwartz and Wagner, 1981). We evaluate how the cooperation probability of a sample of start-up innovators varies with observable characteristics of the commercialization environment. We begin by reviewing the novel dataset employed in this study and discussing our empirical measures in some detail.

3.3.1 The Commercialization Strategies Survey

Our empirical approach requires measuring the commercialization environment and strategy, data that are unavailable from either public or commercial databases (Gompers and Lerner, 1999; Hellman and Puri, 2000). To address this challenge, we developed and administered a start-up commercialization strategy survey (found in the appendix) during the first half of 1999. The survey population is composed of start-ups receiving external R&D financing from one of two sources: private venture capital (VC) or the Small Business Innovation Research program.
(SBIR). Dividing the sample between SBIR and VC-funded firms incorporates variation in the costs of identifying and contracting with partners while maintaining the ability to evaluate the impact of IP strength and sunk costs across a cross-section of firms.

The sample consists of 63 SBIR-backed and 55 VC-backed firms (for a total of 118 observations). Following Lerner (1999a), we use a “matching” process to identify the sample population in an effort to preserve within-sample consistency. First, we collected the sample of SBIR-funded projects (drawn from the top 200 SBIR award winners between 1990 and 1993) and then matched each SBIR project with a single VC-backed project. The matching criteria are based on each firms’ four-digit SIC code, initial sales, and geographic location. The key requirement for inclusion in the sample is that the firm successfully commercialized an externally-funded technology, either independently or through some form of cooperative agreement. This prerequisite ensures that our evaluation of commercialization strategy is conditioned on the fact that the innovation has been commercialized.

The projects are distributed across five SIC codes: biotechnology (2836), computer software (7372), industrial machinery and equipment (35), electronic equipment (36) and scientific instruments (38). We collected data on each firm’s employees, promotion policies, corporate ownership and governance, as well as financial information including expenditures and revenues. For each project, we collected information about commercialization and financing history, revenue information including sales and licensing, the importance of the technology in

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8 The overall survey response rate was approximately 50%. Non-responders seemed to be randomly mixed between firms not having a commercial product and those who declined for other reasons. The respondent was typically the director of R&D, sales or marketing, or the CEO. The surveys were first pre-tested with a small sample of potential respondents. Thereafter, we collected survey responses by phone, fax and mail.

9 Specifically, we first searched the Venture Economics database for candidate venture-backed companies whose primary line of business matched the 4-digit SIC codes for a given SBIR-backed company. Among this set, we eliminated those that themselves received SBIR funding. We then consulted the CorpTech Directory of Technology Companies (1998) to select the firm which most closely matched in initial sales revenues, and where possible, geographic location (Lerner, 1999a).
achieving firm objectives, and the key personnel associated with the firm’s commercialization strategy.\textsuperscript{10} 

It is useful to compare the institutional features associated with the two sources of financing for firms in the sample. The SBIR program provides R&D grants to U.S. firms with 500 or fewer employees (USGAO, 1995). The level of funding for the program by each Federal agency is equal to a fixed percentage of the total level of R&D funding for that agency. Grant applications are peer-reviewed and awarded through a competitive process (less than 15% of applications are granted).\textsuperscript{11} Once awarded, the SBIR grant is a “hands-off” subsidy; the government neither takes over managerial control nor maintains an equity stake in funded organizations. Because it is administered through all R&D-performing Federal agencies, the SBIR program funds a diverse array of firms and technologies relative to the concentrated distribution of private VC financing (Gans and Stern, 2000b). We ensure comparability by evaluating a sample drawn from five industrial segments heavily funded by both VCs and the SBIR program.

In contrast to the SBIR program, VCs provide capital to start-ups in exchange for equity and managerial control. In addition to their financial role, VCs are believed to aid start-up firms by offering a network of contacts and potential partners as well as providing experience in corporate governance (Gompers and Lerner, 1999; Stuart, Hoang and Hybels, 1999). While SBIR and VC-funded projects differ insofar as VC funding directly affects the operation and decision rights of the firm, projects from either source are comparable in several key respects: (a) firms tend to be young,

\textsuperscript{10} When possible, we used publicly available databases to verify survey responses. For example, the number of patents assigned to each organization was verified at www.uspto.gov.

\textsuperscript{11} There are two award types. Phase I awards are proof of concept awards which, during the early 1990s, were capped at $100,000. Phase II awards are development-oriented and were, in the same time period, capped at $750,000 (USGAO, 1995). Our sample of SBIR firms has received Phase II awards. Grants are based, in principle, on three legislative goals: (a) increasing the commercialization rate of innovations derived from Federal R&D, (b) enhancing the “competitiveness” of small firms in technology-intensive sectors, and (c) increasing participation of underrepresented groups in Federal contracting (USGAO, 1995). The policy rationale for the SBIR is a belief that entrepreneurial firms are highly productive, associated with high spillovers and potential R&D under-investment (Lerner, 1999a). However, the program’s objectives and administration may conflict; insofar as administrators may have incentives to grant funding to infra-marginal projects (Wallsten, 2000).
(b) the projects are R&D-intensive, (c) project selection is competitive and (d) the size of financing is comparable in the study period.

3.3.2 Variable Definitions and Summary Statistics

Cooperation measures. Table 3.1 reports variable definitions and summary statistics. Our key dependent variable is a combination of two distinct measures associated with a cooperative commercialization strategy. LICENSED is a dummy variable indicating whether the firm earned licensing revenues from its innovation, a practice undertaken by 22% of the firms in the sample.\footnote{Over 95% of the technology licenses are assigned on an exclusive basis.} Similarly, ACQUIRED is a dummy variable indicating whether the firm was acquired since the project was funded (mean = .14). Together, LICENSED and ACQUIRED form a meaningful concept of cooperative behavior for firms within our sample. In Figure 3B, we plot the percentage of overall revenues derived from cooperation (either through licensing or equal to one if ACQUIRED). The histogram is bimodal; for over 80% of the sample, revenues are derived solely from either licensing/acquisition or from independent commercialization. Accordingly, our key measure of cooperation is COOP (LIC + ACQ), a dummy equal to one if either LICENSED or ACQUIRED is equal to one. It is interesting to note that there is substantial heterogeneity of COOP (LIC + ACQ) across industrial sectors. For example, while the probability of cooperation is above 50% in biotechnology, less than 25% of industrial equipment firms cooperate in commercialization.

We also explore alternative measures of cooperation. First, we explore differences between the determinants of LICENSED and ACQUIRED themselves. As well, building on a mostly descriptive literature highlighting the impact of strategic alliances on cooperative activity (Gomes-Casseres, 1996), we define HI ALLIANCES as a dummy variable equal to one for firms with a high level of strategic alliance activity (in the top quintile). We also group HI ALLIANCES with our previous definition of COOP (LIC + ACQ) to form COOP (ALL) (mean = .41).
Commercialization environment measures. Our analysis relates these cooperation measures to the following variables associated with the strength of IPR, the costs of transacting with potential partners, and the role of sunk cost asymmetries.

We measure the strength of intellectual property in several distinct ways. For most of our analysis, we focus on whether the start-up innovator has received at least one patent associated with the technology (PATENT THRESHOLD = 1). While the mean number of project-specific patents across firms is just over six, less than two-thirds of the sample firms possess at least one patent. To ensure that these measures reflect the commercialization environment at the time of the commercialization strategy choice, we are careful to check that the patents included in our sample are granted prior to the event of cooperation (either acquisition or the receipt of licensing revenues). In addition, we also have collected several more qualitative measures of the level of appropriability (in the spirit of Levin, et al. (1987)). Specifically, we asked each firm to rank several appropriability strategies on a five-point Likert scale, including the importance of patents (PATENT LIKERT) and trade secrecy (SECRETLY LIKERT).

By construction, the sample is (approximately) equally divided between exclusively VC-backed firms (VC = 1) and SBIR-funded firms (VC = 0). This contrast allows us to compare the commercialization strategies of firms who differ in terms of the relative costs of negotiating cooperative agreements with more established firms. While we use the VC dummy in most of the analysis, we also employ an alternative dummy measure, EVER VC-FINANCED, which groups together those firms for whom VC = 1 and those firms initially funded by the SBIR who received some form of venture financing by the end of 1999.

Measuring the investment costs that entrants face in acquiring complementary assets necessary for effective competitive commercialization (relative to the costs associated with a cooperative strategy) is extremely difficult, especially in a cross-industry study. Because "objective" measures of relative investment costs are elusive
(a problem not confined to the current study), we developed a set of five point Likert scales for our survey. Respondents rated the "importance and effectiveness of control" over key assets in earning returns from their innovation: manufacturing, distribution channels, brand development, and servicing. Based on our discussions in field interviews, we believe that respondents rated the importance of each complementary asset element depending on their perception of the relative attractiveness and cost-effectiveness of ownership of that element.

The empirical analysis uses two measures summarizing these survey responses. First, we defined CA LIKERT MAX as the maximum Likert score over the set of questions. The highest level of CA LIKERT MAX (i.e., CA LIKERT MAX = 5) suggests that the respondent perceived that ownership of at least one of the complementary assets elements was cost-effective for earning profits from the innovation. As such, we define EXPENSIVE COMP ASSET OWNERSHIP as a dummy variable equal to one if CA LIKERT MAX is less than five. EXPENSIVE COMP ASSET OWNERSHIP = 1 reflects a perception by the respondent that ownership of relevant complementary assets would not be cost-effective relative to cooperation with pre-existing owners of those assets (mean = .32).

**Firm-level control variables.** A benefit of our survey-based data collection method is our ability to collect detailed firm- and project-level controls for use in the empirical analysis. To control for differences across firms in their resources and capabilities, we measure the pre-innovation size of firms with categorical variables related to INITIAL EMPLOYEE SIZE (while the mean number of initial employees is 25, we group these data into four size categories in the empirical work as the impact of size may vary across its distribution). Two additional variables measure differences among firms in their overall commercialization orientation and strategy. PHD EMP SHARE is the share of firm employees with Ph.D. level training, and CEO FOUNDER is a dummy variable indicating whether the founder of the firm has remained the CEO. Firms with a high PHD EMP SHARE might have specific objectives of avoiding direct entry into product markets, perhaps to maintain a
"scientific" firm culture (Stern, 2000), while the presence of a CEO-founder may be associated with the presence of "empire-building" motives (Roberts, 1991).

**Project-level control variables.** We also define project-level controls to capture the timing and technological type of different innovations. TIME TO MARKET is the time in months from idea conception to first sale of the product. Projects requiring long development times, for example, might be commercialized more frequently via cooperation due to firm resource constraints. Furthermore, YEAR OF PRODUCT INTRO (the year in which a product is initially commercialized) may also impact commercialization strategy, perhaps because of random time-varying market effects.

Finally, the *nature* of the technological innovation may also influence the firm's cooperative behavior. For example, radical innovations may result in more competitive behavior (Reinganum, 1983; Henderson, 1993). We include NOVEL SYSTEM INNOVATION and PRODUCT INNOVATION in the empirical analysis to control for the degree to which the innovation might be incompatible with the incumbent's current technology (for example, almost 40% of the innovations were recorded as "novel systems"). With this data overview in mind, we now turn to our analysis of how start-up commercialization strategy is impacted by the economic environment.

### 3.4 Empirical Results

Our analysis proceeds in three steps. First, we review pairwise and cross-industry correlations to highlight the basic facts present in the data. Second, we present regression estimates relating commercialization strategy to the commercialization environment, exploring various control structures and alternative measures of key variables. Finally, we disaggregate the *form* of cooperation by separating the determinants of licensing and acquisition to examine the sensitivity of the results to our definition of cooperation.
Our analysis begins in Table 3.2 which reports the pairwise conditional means of the probability that COOP (LIC + ACQ) = 1 and each of the three key variables. The results are striking. Changes in each of the (binary) commercialization environment measures are associated with over a 70% increase in the probability of cooperation, in the direction predicted by the model (each of these differences is statistically significant at the 5% level). For example, firms with at least one project-related patent are more than twice as likely to cooperate relative to those with no patents.

In addition, these variables relate to varying commercialization strategy choices across industrial sectors. The first panel of Figure 3C displays a scatter plot of the mean of project-level patenting for each industrial sector and the industry-specific probability of cooperation. Consistent with qualitative assessments of the differences across industries (Gans and Stern, 2001), industries with higher levels of project-level patenting are more likely to pursue a cooperative commercialization strategy. The second panel of Figure 3C reports an analogous result for the industry-specific mean of EXPENSIVE COMP ASSET OWNERSHIP. The probability of cooperation is highest in segments such as biotechnology where the relative costs of acquiring complementary assets are particularly high. While suggestive, these results do not control for project- and firm-level factors, and so we turn to a more systematic regression analysis.

Table 3.3 presents the principal binary probit results. For each specification, the dependent variable is the dummy cooperation measure COOP (LIC + ACQ). Inclusion of all three commercialization environment measures without additional controls shows that each is associated with cooperation, even controlling for the other two (including any two of the three also yields similar results). In addition to their statistical significance (at 5% for PATENT THRESHOLD, just below 5% for VC and EXPENSIVE COMP ASSET OWNERSHIP), the estimates in (3.3-1) suggest strong quantitative effects. A change in one of the three (indicator) variables at the means of
the other variables is associated with a predicted change in the probability of cooperation by 23% (PATENT THRESHOLD), 17.3% (VC), and 18.4% (EXPENSIVE COMP ASSET OWNERSHIP).

So far, we have assumed that the commercialization environment variables are exogenous to the firm's commercialization strategy choice. While this seems reasonable for sunk asset costs associated with product market entry, the observed level of IPR and VC funding might be related to the firm's commercialization strategy. We, therefore, paid close attention to the sequence of commercialization events. Specifically, we checked that patent awards and external financing by VCs and the SBIR program preceded cooperation events. Of course, the sequencing of events does not make these variables predetermined, so the remainder of Table 3.3 exploits our detailed survey data to provide industry-, firm-, and project-level controls for omitted factors potentially correlated with commercialization strategy and the commercialization environment.

In (3.3-2), we include industry segment dummies, suggesting evidence for our key hypotheses in the within-industry variation of commercialization strategy. As well, the positive coefficient on BIOTECHNOLOGY suggests that some segments offer an extremely favorable environment for cooperation, above and beyond our commercialization environment measures.

We then turn to analyses addressing the chief "candidate" for potential bias: our inability to fully control for the underlying quality of projects. It is possible that PATENT THRESHOLD and VC-FUNDED are also associated with higher quality projects. We address this issue in three ways. First, we include several controls for the type of technology and the timing of product introduction (3.3-3). Neither the time from project conception to product introduction nor the type of technology impact commercialization strategy; as well, our commercialization environment results remain effectively unchanged. While these results are in contrast to the prior (mostly theoretical) literature highlighting the importance of the pro-competitive

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Note that the construction of the sample through matched VC and SBIR-funded firm pairs implies
effects of "radical" technologies, we do not overemphasize these findings, as the type of innovation is self-reported by each firm. Our main point is simply that our core results are robust to project-level measures of innovation "radicalness," such as NOVEL SYSTEM INNOVATION. Second, we ran a number of specifications including measures of project-level "performance" as an explanatory variable in the cooperation probit, including, among others, TOTAL PROJECT REVENUES and 1998 PROJECT REVENUES. Of course, project-level performance measures are endogenous to chosen commercialization strategy (and so we do not report these results formally). However, it is interesting to note that (a) measures of project-level performance are positively correlated with COOP (LIC+ACQ) and (b) inclusion of project-level performance measures substantially strengthens each of the commercialization environment estimates. Our results are therefore robust to the inclusion of measures of realized project quality.

Finally, conflating strong IPR or association with VCs with "high-quality" projects likely reduces the power of our empirical work to detect the impact of the commercialization environment. Suppose that control of IP (or association with VCs) is simply proxying for "high-quality" or "radical" projects. Most earlier research would then suggest that our measures of the commercialization environment would be associated with higher rates of independent product market entry (Foster, 1986; Christensen, 1997), implying that our empirical work is providing a lower bound on the impact of the commercialization environment measures.

Additional potential sources of unobserved differences exist at the firm level. Specifically, firms may differ in the resources available for commercialization or in their overall corporate strategy (beyond the specific project included in our sample). In (3.3-4), we include controls for initial firm size (divided into categories since preliminary empirical analysis suggested the relationship may be nonlinear). Interestingly, relative to firms with the largest initial sizes in our sample (the excluded category), smaller firms are not significantly more likely to cooperate (indeed, the

that the mean of VC will be constant across industrial segments.
estimates for each of the included categories is negative). In the final column of Table 3.3, we include all of our prior controls together as well as two additional firm-level controls, CEO FOUNDER and PHD-TRAINED EMPS. In line with our other findings, the commercialization environment variables continue to have similar predicted effects on commercialization strategy, with little evidence that the composition of employees or ownership impacts the probability of cooperation.

By simultaneously including industry-, firm-, and project-level variables, we control for many potential sources of unobserved heterogeneity in the data. As well, we ran a wide number of additional specifications to establish robustness of the key results. In addition, we experimented with an instrumental variables procedure where, for firm j, we instrument for PATENT THRESHOLD with the average, excluding firm j, of PATENTS and PATENT LIKERT in firm j’s industry segment. While the results on the complementary asset variables tend to be reduced in significance, our results regarding the role of IPR and VC-FUNDED continue to be robust.14

Taken together, we interpret these results as providing support for a model in which start-up innovators earn their returns on innovation through the market for ideas when the environment offers a strong intellectual property regime, and, at the same time, the start-up faces high relative costs in acquiring and controlling key complementary assets necessary for commercialization success. As imperfections arise in the market for ideas (e.g., through increases in the expropriation hazard), start-up innovators are more likely to pursue competitive strategies, which in turn contribute to the gale of creative destruction.

Alternative Measures. In Table 3.4, we document the robustness of our core results to alternative measures of the key variables. This is particularly important in the context of exploring a novel dataset in which we had some latitude in defining the variables used in the analysis. In (3.4-1) and (3.4-2), we employ Likert-based measures of strength in the IPR regime, PATENT LIKERT and SECRECY LIKERT.

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14 We do not separately report these results since the essential empirical relationship is highlighted in Figure 3C (which suggests that the substantial cross-industry variation in the rate of cooperation is related to the variation in the commercialization environment across sectors).
While the results are indeed robust to PATENT LIKERT, the SECRECY LIKERT measure, when used as the sole proxy for IP regime weakens the result (though VC-FUNDED and EXP. COMP ASSET OWNERSHIP remain significant). When PATENT THRESHOLD is included with SECRECY LIKERT (equation 3.4-2), the former variable is significant (as are our other core results). While PATENT THRESHOLD and PATENT LIKERT may each have their own interpretational problems,15 the robust relationship between each and COOP (LIC + ACQ) provides supporting evidence for one of our key hypotheses: stronger intellectual property protection is associated with higher levels of cooperation between start-up entrants and incumbents.

Next, we vary the measure of external project funding in equation (3.4-3) to include projects that have ever been funded by venture capital. EVER VENTURE-FUNDED is a variable that includes SBIR-backed firms that went on to receive VC funding by the beginning of 1999. This variable captures the idea that entrants associated at any time with VCs may face lower transaction costs in transacting with established firms. Each of the key variables remains robust to the inclusion of this measure. Our results are also robust to an alternate measure of the complementary asset regime. CA LIKERT MAX, the maximum value of the set of Likert measures of the importance of complementary assets in earning returns from the firm’s innovation, is marginally significant at the 10% level (3.4-4), suggesting that the absence of cost-effective competitive commercialization investments makes cooperation more likely.

Finally, recognizing that the definition of cooperation itself is subject to interpretation, (4-5) includes a broader definition (COOP), which adds firms with HI ALLIANCES = 1 to the set of cooperators in the sample. Though the magnitude and significance of VC-FUNDED is modestly reduced, our results regarding PATENT THRESHOLD and EXP. COMP ASSET OWNERSHIP remain unchanged.

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15 For example, PATENT THRESHOLD might be proxying for quality while it is difficult to ensure comparability from Likert-based survey responses.
Form of Cooperation. We conclude the empirical analysis by “unbundling” the COOP (LIC + ACQ) measure to explore whether an alternate definition alters our results. Table 3.5 shows the results of multinomial logits using a dependent variable of LICENSED or ACQUIRED (the default commercialization choice is “compete”). Disaggregating the dependent variable in this way yields additional insight into the nature of cooperation. In equation (3.5-1), note that licensing behavior is associated with the IPR and complementary asset regimes, whereas acquisitions are associated with VC funding. The final regression, (3.5-2), includes industry dummies, which do not alter the PATENT THRESHOLD or VC-FUNDED effects, but weakens the EXP. COMP ASSET OWNERSHIP result (to just below the 10% significance level). These results suggest that technology licenses depend importantly on the strength of intellectual property protection, and that VCs may help facilitate acquisition rather than licensing or competition activity.

3.5 Discussion and Conclusions

In economic environments such as those observed in the biotechnology industry, where patents are relatively effective in protecting IPR, firms face high relative investment costs, and brokers such as VCs are available to facilitate trade, start-up innovators tend to earn their returns from innovation through the market for ideas, acting as an upstream supplier of “technology” rather than as a horizontal innovation-oriented competitor. In contrast, when investment costs for the entrant are relatively low and the technological innovation is not protected by patents, as in the disk drive industry, the severe disclosure threat tends to foreclose the ideas market. Start-up innovators in this environment are more likely to commercialize their innovations through product market competition.

We found empirical support for these ideas using a novel sample of the commercialization strategies of 118 start-ups. Perhaps most strikingly, firms who control IPR are more likely to pursue a cooperative strategy. These results suggest
that the role of intellectual property on the competitiveness of product markets is subtle. While most prior work has emphasized the fact that a strong intellectual property position increases the absolute returns to innovation, our evidence is consistent with a somewhat more nuanced idea – that increases in the strength of intellectual property increase the relative returns to cooperation by facilitating the market for ideas.

The study is not without limitations. First, the empirical measures may be imperfect in capturing the key concepts from the theoretical model. The results are robust, however, to alternative measures of both cooperation and the start-up’s commercialization environment, increasing our confidence in the results. Second, our measures of the commercialization environment may be endogenous. We addressed this issue in two ways: (1) the sample was constructed so as to include only pre-existing patent and external funding events relative to cooperation events; and (2) we include detailed controls to limit the risk of omitting variables that may be correlated with both the start-up’s commercialization strategy and its commercialization environment. Finally, the control of IPR or association with VCs may be correlated with underlying project quality. Our results are, however, robust to controls for both the type and size of innovation. Indeed, cooperation is positively associated with a revenue-based measure of the realized commercial returns from the project. Whereas most earlier research assumes or suggests that product market entry and competition would be associated with projects with higher quality (Christensen, 1997), our findings suggest that projects able to obtain IPR, funded by venture capitalists, and associated with higher revenues are all more likely to be commercialized through cooperation.

These findings suggest several directions for further research. First, we plan to investigate commercialization strategies for both entrants and incumbents in “mixed” economic environments. For example, in environments where IPR are weak and a dominant incumbent would prefer to take advantage of the R&D productivity of smaller firms, established firms may be motivated to develop a reputation for “non-
expropriation” in order to provide incentives for innovation and cooperation by start-ups. Indeed, Gawer (2000) finds qualitative evidence for this hypothesis in the semiconductor industry. Second, our findings suggest that venture capitalists play a non-financial role in the strategy of start-up firms. Identifying the mechanisms by which VCs facilitate transactions and whether they earn additional economic returns by doing so remains an additional area for further investigation.
Figure 3A. Start-Up Choices and Payoffs

Diagram showing the decision process between "Cooperate" and "Compete" with different outcomes for imitation, disclosure, and enforcement of IP. The diagram includes probabilities and payoffs for each decision path.
Figure 3B. Share of Revenues from Cooperation: Frequency Distribution
Figure 3C. Probability of Cooperation by Industry and Key Variables
<table>
<thead>
<tr>
<th>VARIABLE</th>
<th>DEFINITION</th>
<th>MEAN</th>
<th>STD. DEV.</th>
<th>SOURCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COOPERATION DUMMIES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LICENSED</td>
<td>Dummy = 1 if licensing revenues &gt; 0</td>
<td>0.220</td>
<td>0.416</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>ACQUIRED</td>
<td>Dummy = 1 if firm acquired since project initiation</td>
<td>0.144</td>
<td>0.353</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>HI ALLIANCES</td>
<td>Dummy = 1 if firm's strategic alliance activity is in the top ten percent</td>
<td>0.110</td>
<td>0.314</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>COOP (LIC + ACQ)</td>
<td>Dummy = 1 if LICENSED = 1 or ACQUIRED = 1</td>
<td>0.339</td>
<td>0.475</td>
<td>Authors Calculation</td>
</tr>
<tr>
<td>COOP (ALL)</td>
<td>Dummy = 1 if LICENSED = 1 or ACQUIRED = 1 or HI ALLIANCES = 1</td>
<td>0.407</td>
<td>0.493</td>
<td>Authors Calculation</td>
</tr>
<tr>
<td><strong>APPROPRIABILITY MEASURES</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PROJECT PATENTS</td>
<td># patents associated with project</td>
<td>6.678</td>
<td>14.189</td>
<td>MIT Survey, USPTO</td>
</tr>
<tr>
<td>PATENT THRESHOLD</td>
<td>Dummy = 1 if at least one patent has been granted to this project</td>
<td>0.653</td>
<td>0.478</td>
<td>MIT Survey, USPTO</td>
</tr>
<tr>
<td>PATENT LIKERT</td>
<td>5-Point Likert scale rating of importance of patents for appropriating returns</td>
<td>3.475</td>
<td>1.478</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>SECRECY LIKERT</td>
<td>5-Point Likert scale rating of importance of trade secrecy for appropriating returns</td>
<td>3.678</td>
<td>1.371</td>
<td>MIT Survey</td>
</tr>
<tr>
<td><strong>FUNDING SOURCE MEASURE</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VC-FUNDED</td>
<td>Dummy = 1 if project is initially VC-funded</td>
<td>0.466</td>
<td>0.501</td>
<td>MIT Survey, Venture Ec.</td>
</tr>
<tr>
<td><strong>COMPLEMENTARY ASSET MEASURES</strong></td>
<td>Max over 5-point Likert scales measuring the importance and effectiveness of ownership of complementary assets (Branding, Manufacturing, Distribution, &amp; Service).</td>
<td>4.627</td>
<td>0.596</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>EXPENSIVE COMP ASSET OWNERSHIP</td>
<td>Dummy = 1 if CA LIKERT MAX &lt; 5</td>
<td>0.322</td>
<td>0.469</td>
<td>MIT Survey</td>
</tr>
<tr>
<td><strong>FIRM-LEVEL CONTROLS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INIT. EMPLOYEES</td>
<td># of employees at project initiation</td>
<td>25.481</td>
<td>43.662</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>CEO FOUNDER</td>
<td>Dummy = 1 if current CEO is firm founder</td>
<td>0.598</td>
<td>0.492</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>PHD EMP SHARE</td>
<td>Share of employees with Ph.D. education</td>
<td>0.142</td>
<td>0.177</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>INDUSTRY SEGMENTS</td>
<td>Dummy variable for primary SIC industrial segment: biotechnology, industrial equipment, instruments, and software</td>
<td></td>
<td></td>
<td>Corptech Directory</td>
</tr>
<tr>
<td><strong>PROJECT-LEVEL CONTROLS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TIME TO MARKET</td>
<td>Time in months from conception of product idea to first sale</td>
<td>44.925</td>
<td>49.068</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>YEAR OF PRODUCT INTRO</td>
<td>First year in which product was introduced for commercial sale</td>
<td>92.492</td>
<td>4.644</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>PRODUCT INNOVATION</td>
<td>Dummy = 1 if the project results in a product innovation</td>
<td>0.678</td>
<td>0.469</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>NOVEL SYSTEM INNOVATION</td>
<td>Dummy = 1 if the project results in a novel overall system</td>
<td>0.373</td>
<td>0.486</td>
<td>MIT Survey</td>
</tr>
<tr>
<td>MASS-PRODUCED PRODUCT</td>
<td>Dummy = 1 if the technology requires mass production</td>
<td>0.636</td>
<td>0.483</td>
<td>MIT Survey</td>
</tr>
<tr>
<td></td>
<td>Patent Threshold</td>
<td>VC Funded</td>
<td>Expensive Comp Asset Ownership</td>
<td></td>
</tr>
<tr>
<td>------------------------------</td>
<td>------------------</td>
<td>-----------</td>
<td>--------------------------------</td>
<td></td>
</tr>
<tr>
<td></td>
<td>= 0</td>
<td>= 1</td>
<td>= 0</td>
<td>= 1</td>
</tr>
<tr>
<td>COOP (LIC + ACQ) = 1</td>
<td>0.20</td>
<td>0.42</td>
<td>0.25</td>
<td>0.44</td>
</tr>
<tr>
<td>t-stat for equality of means</td>
<td>2.45</td>
<td></td>
<td>2.15</td>
<td>2.11</td>
</tr>
</tbody>
</table>
### Table 3.3
**Cooperation Probits**

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>(3.3-1) Baseline</th>
<th>(3.3-2) (3-1) w/ industrial segments</th>
<th>(3.3-3) (3-2) w/ project &amp; firm controls</th>
<th>(3.3-4) (3-1) w/ initial employee size</th>
<th>(3.3-5) (3-1) w/ all segment, project &amp; firm controls</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Patent Threshold</strong></td>
<td>0.684 (0.273)</td>
<td>0.674 (0.292)</td>
<td>0.636 (0.298)</td>
<td>0.645 (0.278)</td>
<td>0.647 (0.317)</td>
</tr>
<tr>
<td><strong>VC-funded</strong></td>
<td>0.481 (0.250)</td>
<td>0.553 (0.261)</td>
<td>0.589 (0.272)</td>
<td>0.478 (0.262)</td>
<td>0.730 (0.309)</td>
</tr>
<tr>
<td><strong>Exp. Comp Asset Ownership</strong></td>
<td>0.497 (0.262)</td>
<td>0.458 (0.273)</td>
<td>0.513 (0.286)</td>
<td>0.491 (0.273)</td>
<td>0.499 (0.303)</td>
</tr>
<tr>
<td><strong>Industry Segments (Default = Electronic Equipment)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Biotechnology</strong></td>
<td>0.862 (0.405)</td>
<td>1.043 (0.497)</td>
<td></td>
<td></td>
<td>0.895 (0.537)</td>
</tr>
<tr>
<td><strong>Industrial Equipment</strong></td>
<td>-0.179 (0.492)</td>
<td>-0.160 (0.505)</td>
<td></td>
<td></td>
<td>-0.108 (0.545)</td>
</tr>
<tr>
<td><strong>Instruments</strong></td>
<td>0.209 (0.323)</td>
<td>0.069 (0.343)</td>
<td></td>
<td></td>
<td>0.015 (0.356)</td>
</tr>
<tr>
<td><strong>Software</strong></td>
<td>0.141 (0.468)</td>
<td>0.042 (0.035)</td>
<td></td>
<td></td>
<td>-0.054 (0.556)</td>
</tr>
<tr>
<td><strong>Firm-level Controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CEO Founder</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.194 (0.275)</td>
</tr>
<tr>
<td>Init. Emps (1-2)</td>
<td></td>
<td></td>
<td>-0.261 (0.581)</td>
<td>-0.195 (0.641)</td>
<td></td>
</tr>
<tr>
<td>Init. Emps (3-10)</td>
<td></td>
<td></td>
<td>-0.518 (0.510)</td>
<td>-0.543 (0.573)</td>
<td></td>
</tr>
<tr>
<td>Init. Emps (11-74)</td>
<td></td>
<td></td>
<td>-0.177 (0.499)</td>
<td>-0.075 (0.560)</td>
<td></td>
</tr>
<tr>
<td>Phd Emp Share</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.014 (0.010)</td>
</tr>
<tr>
<td><strong>Product-level Controls</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time to Market</td>
<td></td>
<td>0.001 (0.003)</td>
<td></td>
<td>-0.001 (0.003)</td>
<td></td>
</tr>
<tr>
<td>Year of Product Introduction</td>
<td>-0.043 (0.035)</td>
<td></td>
<td></td>
<td>-0.051 (0.036)</td>
<td></td>
</tr>
<tr>
<td>Product Innovation</td>
<td></td>
<td>0.178 (0.313)</td>
<td></td>
<td></td>
<td>0.203 (0.334)</td>
</tr>
<tr>
<td>Novel System Innovation</td>
<td>-0.140 (0.285)</td>
<td></td>
<td></td>
<td></td>
<td>-0.157 (0.302)</td>
</tr>
<tr>
<td>Mass-produced Product</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-0.127 (0.321)</td>
</tr>
<tr>
<td>Constant</td>
<td>-1.288 (0.280)</td>
<td>-1.503 (0.377)</td>
<td>2.433 (3.149)</td>
<td>-0.938 (0.526)</td>
<td>3.523 (3.294)</td>
</tr>
<tr>
<td>LL</td>
<td>-68.338</td>
<td>-65.511</td>
<td>-64.248</td>
<td>-67.107</td>
<td>-61.760</td>
</tr>
</tbody>
</table>

N = 118 observations
<table>
<thead>
<tr>
<th></th>
<th>Dependent Variable = COOP (LIC + ACQ)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(3.4-1) PATENT LIKERT</td>
</tr>
<tr>
<td></td>
<td>measure for IP strength</td>
</tr>
<tr>
<td>PATENT THRESHOLD</td>
<td>0.208 (0.103)</td>
</tr>
<tr>
<td>PATENT LIKERT</td>
<td></td>
</tr>
<tr>
<td>SECRECY LIKERT</td>
<td>0.084 (0.096)</td>
</tr>
<tr>
<td>VC-FUNDED</td>
<td>0.487 (0.249)</td>
</tr>
<tr>
<td>EVER VENTURE-FUNDED</td>
<td></td>
</tr>
<tr>
<td>EXP. COMP ASSET</td>
<td>1.452 (0.785)</td>
</tr>
<tr>
<td>OWNERSHIP</td>
<td></td>
</tr>
<tr>
<td>CA LIKERT MAX</td>
<td></td>
</tr>
<tr>
<td>EXP. COMP ASSET * PATENT LIKERT</td>
<td>0.275 (0.199)</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-1.537 (0.420)</td>
</tr>
<tr>
<td>LL</td>
<td>-69.429</td>
</tr>
</tbody>
</table>
### TABLE 3.5
COOPERATION MULTINOMIAL LOGITS

Dependent Variable = LICENSED or ACQUIRED
(DEFAULT = COMPETE)

\( N = 118 \) observations

<table>
<thead>
<tr>
<th></th>
<th>(3.5-1)</th>
<th></th>
<th>(3.5-2)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LICENSED = 1</td>
<td>ACQUIRED = 1</td>
<td>LICENSED = 1</td>
<td>ACQUIRED = 1</td>
</tr>
<tr>
<td>PATENT THRESHOLD</td>
<td>1.660</td>
<td>0.719</td>
<td>1.667</td>
<td>0.603</td>
</tr>
<tr>
<td></td>
<td>(0.674)</td>
<td>(0.610)</td>
<td>(0.771)</td>
<td>(0.629)</td>
</tr>
<tr>
<td>VC-FUNDED</td>
<td>0.358</td>
<td>1.587</td>
<td>0.475</td>
<td>1.684</td>
</tr>
<tr>
<td></td>
<td>(0.505)</td>
<td>(0.626)</td>
<td>(0.538)</td>
<td>(0.647)</td>
</tr>
<tr>
<td>EXP. COMP ASSET</td>
<td>1.001</td>
<td>0.602</td>
<td>0.868</td>
<td>0.724</td>
</tr>
<tr>
<td>OWNERSHIP</td>
<td>(0.512)</td>
<td>(0.582)</td>
<td>(0.541)</td>
<td>(0.625)</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-2.974</td>
<td>-3.125</td>
<td>-3.019</td>
<td>-3.972</td>
</tr>
<tr>
<td></td>
<td>(0.715)</td>
<td>(0.735)</td>
<td>(0.861)</td>
<td>(0.975)</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-92.826</td>
<td></td>
<td>-86.543</td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX 3A.

MIT SLOAN SCHOOL
COMMERCIALIZATION STRATEGIES SURVEY

Principal Investigator: Professor Scott Stern, MIT Sloan School & NBER
Researchers: David Hsu, MIT; Joshua Gans, University of Melbourne

The goal of this project is to evaluate how companies commercialize innovative new technologies. We are exploring different commercialization strategies and how success at a technical level affects firm strategy.

Enclosed is a survey, which asks you to describe the circumstances surrounding a specific innovative project or initiative. We would like to focus on your firm’s involvement in its main business area. Within that frame, please choose a research and/or development project which is internally perceived as an important source of value for your firm. We would like you to choose a project which provided direct financial returns for the firm, through direct sales, licensing agreements, or in strengthening the bargaining position of the firm.

Once the project is chosen, the survey is divided into two parts:

- General background of your company
- Commercialization history of the innovation

Participation in this study is entirely voluntary, and you can decline to answer any questions or decline further participation at any time. The survey should take no more than 25 minutes to complete. Responses will be kept both confidential and anonymous. Please return this survey and direct inquiries to:

Professor Scott Stern
MIT Sloan School
E52-554
Cambridge, MA 02142
TEL: 617-253-5219
FAX: 617-253-2660
e-mail: sstern@mit.edu

Thank you for your participation!
MIT SLOAN SCHOOL
COMMERCIALIZATION STRATEGIES SURVEY

Name of Firm: ____________________________

Year Founded: 19____

Part I: Background Information

A. Employee Information

# of Employees: ____________
At the start of chosen project ____________
Currently ____________

What share of employees hold as their highest degree: BA/BS ____________
Master's ____________
Ph.D. ____________

What share of employees have backgrounds in:
Engineering ____________
Science ____________

Is there a management track for technically trained employees? □ Yes □ No
Are senior managers promoted from within the firm? □ Yes □ No

Please rank the relative importance of the following factors in determining the promotion of
scientists & engineers (with 1 = most important – 4 = least important):

<table>
<thead>
<tr>
<th>Factor</th>
<th>Rank</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>External research reputation</td>
<td>_____</td>
<td>2</td>
</tr>
<tr>
<td>Demonstrated contribution to R&amp;D teams</td>
<td>_____</td>
<td>3</td>
</tr>
<tr>
<td>Demonstrated contribution to cross-functional teams</td>
<td>_____</td>
<td>1</td>
</tr>
<tr>
<td>Management ability</td>
<td>_____</td>
<td>4</td>
</tr>
</tbody>
</table>

B. Financial Information

What is the percentage of corporate ownership held by the following groups:

<table>
<thead>
<tr>
<th>Public</th>
<th>Top Mgmt.</th>
<th>Employees</th>
<th>Venture Capitalists</th>
<th>&quot;Angel&quot; Investors</th>
<th>Other: ________</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
</tr>
</tbody>
</table>

What mechanisms are used to fund new technology development or R&D projects (check all that apply):
□ Internal Cash □ Loans □ Contract Research □ Equity
□ Partnering w/ Suppliers □ Partnering w/ Customers □ Other: ____________________________

What is the percentage of gross revenues devoted towards:

<table>
<thead>
<tr>
<th>R&amp;D Development</th>
<th>New Product Development</th>
<th>Marketing</th>
</tr>
</thead>
<tbody>
<tr>
<td>_____%</td>
<td>_____%</td>
<td>_____%</td>
</tr>
</tbody>
</table>
Number of patents issued directly related to this technology: _____

Number of patents issued to your organization since founding: _____

Please check the terms which best describe this technology:
☐ Assembled  ☐ Non-Assembled

Please check the terms which best describe the innovation (check all that apply):
☐ Product Innovation
☐ Process Innovation
☐ Novel components within a relatively standard system
☐ Novel overall system

What year was the product’s first commercial introduction? 19___

Time from conception of technology to first prototype: _____ months

Time from prototype to first sale: _____ months

Financing history of this project:

<table>
<thead>
<tr>
<th>Year</th>
<th>Source</th>
<th>Amount</th>
</tr>
</thead>
</table>

For this project, what activities did the following actors facilitate?

<table>
<thead>
<tr>
<th>Activity</th>
<th>venture capitalist</th>
<th>angel investor</th>
<th>other board members</th>
<th>legal counsel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locating key personnel such as managers and technologists</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Locating sources of additional capital</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Gaining access to critical technologies</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Increasing the firm’s focus on a small number of projects, technologies,</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>or markets</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Locating and arranging introductions with potential alliance partners</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Participating in discussions over licensing and commercialization strategies</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other (specify)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
Total sales for your company: When the project was initiated $__________
In 1998 $__________

C. Organizational Governance & Structure

# of Directors: __________

What share of directors are: Internal ___% External ___% Venture Capital Appointed ___%

Which characteristics in the first column apply to the following executives?

<table>
<thead>
<tr>
<th>Firm founder</th>
<th>CEO</th>
<th>President</th>
<th>R&amp;D or Technology Director</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Promoted from within</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Hired externally</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
<tr>
<td>Has run other companies</td>
<td>□</td>
<td>□</td>
<td>□</td>
</tr>
</tbody>
</table>

How many distinct products does your firm develop? ______

How many alliances has your company entered into with another firm? ______

What were the nature of these alliances? □ R & D □ Product Development □ Manufacturing □ Sales/Marketing □ Distribution

Has your firm entered into any licensing deals? □ Yes: licensed-out □ Yes: licensed-in □ No

If your firm has licensed-out, what were the total licensing revenues? 1998 $_____ Total $_____

What were the terms? □ Exclusive □ Non-Exclusive

Who were the licensees? (mark all that apply)

□ Product Market Incumbents □ Product Market Entrants
□ Government Agencies □ Non-market agents (e.g., universities)

Part II: Commercialization History of Chosen Project

Name of technology/product: ____________________________________________.
Brief description of the technology: ________________________________________

Was this technology originated from research and development performed at your firm? □ Yes □ No

If the technology did not originate from your firm, where did it come from?

□ Licensed from parent firm □ Licensed from university
□ Licensed from corporate lab □ Other: ____________________
Number of patents issued directly related to this technology:  

Number of patents issued to your organization since founding:  

Please check the terms which best describe this technology:  
☐ Assembled  ☐ Non-Assembled  

Please check the terms which best describe the innovation (check all that apply):  
☐ Product Innovation  
☐ Process Innovation  
☐ Novel components within a relatively standard system  
☐ Novel overall system  

What year was the product’s first commercial introduction?  19___  

Time from conception of technology to first prototype:  _______ months  

Time from prototype to first sale:  _______ months  

Financing history of this project:  

<table>
<thead>
<tr>
<th>Year</th>
<th>Source</th>
<th>Amount</th>
</tr>
</thead>
</table>

For this project, what activities did the following actors facilitate?  

<table>
<thead>
<tr>
<th>Activity</th>
<th>venture capitalist</th>
<th>angel investor</th>
<th>other board members</th>
<th>legal counsel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Locating key personnel such as managers and technologists</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Locating sources of additional capital</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Gaining access to critical technologies</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Increasing the firm’s focus on a small number of projects, technologies, or markets</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Locating and arranging introductions with potential alliance partners</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Participating in discussions over licensing and commercialization strategies</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Other (specify)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
What are the sources of revenue (on a percentage basis) associated with this technology?

<table>
<thead>
<tr>
<th>Sales</th>
<th>Licensing Revenue</th>
<th>Intellectual Property Asset Sale</th>
</tr>
</thead>
<tbody>
<tr>
<td>____%</td>
<td>____%</td>
<td>____%</td>
</tr>
</tbody>
</table>

Share of revenues of this project from government contracts: ____%

What is the number of distinct customers for this project?:

- [ ] < 10
- [ ] 10 - 100
- [ ] 101 – 500
- [ ] > 500

Form of sales (check all that apply):

- [ ] made to order
- [ ] mass produced
- [ ] mass customized

Total sales of the product

- Sales attributable to this product in 1998? $______
- Sales attributable to this product since the inception of this project? $______

Has your firm been acquired since the development of this technology?  [ ] Yes  [ ] No

If so, by whom? __________________________________________

Does the new firm (after the merger) have more than 500 employees? [ ] Yes  [ ] No

Why did your company decide to undergo an acquisition? __________________________________________

Has the product been substantially modified/upgraded since development of the first working prototype?

- [ ] No  [ ] Yes; If yes, please describe the modifications: __________________________________________

If this technology resulted in licensing revenues,

- What was the first year in which the technology was licensed? 19____
- What was the licensing revenue? 1998 $______ Total $______
- What were the terms? [ ] Exclusive  [ ] Non-Exclusive
- Were other technologies bundled in the license? [ ] Yes  [ ] No

Who were the licensees? (mark all that apply)

- [ ] Product Market Incumbents
- [ ] Government Agencies
- [ ] Product Market Entrants
- [ ] Non-market agents (e.g., universities)

Why did your company decide to license-out this technology? __________________________________________
Please rate the importance of the strategic goals this technology enabled for your company:

<table>
<thead>
<tr>
<th>Goal</th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attraction of venture capital or outside funding</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Attraction of scientists or other employees</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Enable further government grants</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Provided visibility of the company to customers or suppliers</td>
<td>N/A</td>
<td>1</td>
</tr>
<tr>
<td>Was an important factor for the firm getting acquired</td>
<td>N/A</td>
<td>1</td>
</tr>
</tbody>
</table>

Who were the key personnel involved in formulating the commercialization strategy for this product?

☐ CEO  ☐ Technology/R&D Manager  ☐ Marketing and sales manager

You mentioned before that the project's first prototype was developed around 19__. From that time onwards, your success with this technology likely depended, at least in part, on your control of resources which were not directly linked to the technology itself and on your ability to protect the innovation from imitation by others through intellectual property protection. Let’s first consider how important your firm’s control over resources has been in earning profits from this innovation. For each factor below, rate the importance of control over this resource on a scale from 1 to 5. A rating of “5” would mean that control over this resource was critical for earning profits from this innovation while a “1” would imply that control over this resource was not important at all.

<table>
<thead>
<tr>
<th>Resource</th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>The capability to manufacture the product</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>The principal distribution channels for the technology</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>The association of the technology with a well-known brand name or the development of a brand name for the product through marketing or advertising</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Control over the sales force and servicing resources for this product or technology</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

Now, let’s turn to your ability to protect the innovation from imitation by others through intellectual property protection. For each factor below, rate the effectiveness of each factor in deterring imitation of the technology on a scale from 1 to 5. A rating of “5” would mean that this factor was very effective in deterring imitation of the technology while a rating of “1” implies that this factor had no impact on your ability to deter imitation.

<table>
<thead>
<tr>
<th>Protection Method</th>
<th>LOW</th>
<th>HIGH</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trade secrecy</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Patents &amp; copyright protection</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Active patent or copyright litigation</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>

What activities were involved in the process of commercializing this technology and deciding how to earn returns from the innovation?

☐ Took an outside offer for purchasing the rights to the technology
☐ Shopped the technology around but was unable to sell a license to the technology
☐ Shopped the technology around and sold a license to the technology
☐ Did not shop the technology: Always had the intention of competing with the technology
☐ Other: __________________________________________________________________________
Chapter Four

The Evolution and Entry of Organizational Forms in Financing and Developing High-Technology Start-ups: A Preliminary Study

4.1 Overview

As financial institutions meant to address capital constraints to start-ups, organized venture capital has become an important part of the U.S. innovation system. Neither the practices associated with financing early stage ventures, nor the organizational form of providing entrepreneurial finance has been constant over time, however. Exploring the evolution of VC financing practices may offer insight into the challenges of funding early stage entrepreneurs and how those challenges have changed over time. Likewise, examining the entry of alternate organizational forms of entrepreneurial finance may shed light on the structure and practices of VC that have enabled such entry. This chapter therefore explores two distinct but related research questions: (1) why has the VC form of organizing entrepreneurial finance evolved the way it has? and (2) what factors facilitated entry by alternate organizational forms in entrepreneurial finance? To address the first question, I examine the evolution of financing practices of one early VC organization, American Research & Development, over time in sections 4.2 through 4.4. To address the second question, in section 4.5 I present two puzzles in venture capital finance, that VC investments leave a funding "gap," or shortfall, for early stage ventures and that VC investments are concentrated, as measured by both industry segment and geographic location. A qualitative case study of the experience of funding cardiovascular medical device firms illustrates the former puzzle. The thesis of the second half of the chapter is that entry of new organizational forms resulted from opportunities afforded by both the institutional structure of VC and the business environment faced by VCs. These new
forms, however, do not seem to replace VCs so much as complement them, resulting in a system of financial institutions involved in the process of commercializing innovations. A concluding section (4.6) discusses the limitations of the present study and suggests directions for future research.

4.2 American Research & Development: Background

4.2.1 Introduction

American Research & Development (ARD) was created in Boston in 1946 as a way to provide organized risk capital for new venture creation. ARD was among the first organized VC firms, and the first to raise its funds from institutional investors. By examining the investment practices of this early VC firm, we can gain insight on the experimentation and learning associated with funding new research and development-based ventures. The goal of sections 4.2 through 4.4 is to serve as a preliminary study in addressing the research question: why has the VC form of organizing entrepreneurial finance evolved the way it has?

While comprehensively addressing this question requires detailed data spanning 50 years to draw causal inferences about the factors that spurred the evolution of VC organizational structure and practices, the present study is much less ambitious. It takes the first step in addressing the research question by presenting quantitative and qualitative evidence about the evolution of financing practices at one VC firm, ARD. While ARD's practices will be contrasted with those of modern-day VCs, a large time gap filled with factors influencing VC evolution will have to be left to future study. Examining ARD's financing practices, however, provides a fruitful research setting for beginning to understand the evolution of VC practices for three reasons. First, ARD was an early VC company which adopted both practices now common (e.g., active management) and no longer common (e.g., debt-based financing) in the VC industry. Secondly, from a data-collection perspective, because
ARD is now a defunct firm, examining and reporting on its practices would not compromise its strategic position, a statement that may not be true for ARD's contemporaries. By drawing on both primary and secondary ARD documents¹, I am able to provide some novel perspectives on the evolution of practices at this company. Finally, ARD represents a landmark company in spreading managerial practices at VC organizations because several ex-ARD personnel spawned the next generation of important VC companies, such as Greylock and Morgan-Holland. ARD therefore represents one of the important "seeds" from which subsequent venture capitalists learned, both directly and indirectly. However, because ARD was just one organization, we must be cautious about over-interpreting this firm's experience and influence on shaping the evolution of the modern VC organization. After a brief discussion of the circumstances surrounding the birth of organized venture capital, I use a combination of quantitative and qualitative evidence to analyze organizational practices over time at ARD. These practices include choices to fund firms of a given stage of development, location, and industry, as well as the method of financing these affiliates.

4.2.2 The Birth of ARD

ARD, incorporated in June 1946, was conceived by Ralph Flanders, then President of the Boston branch of the Federal Reserve and trustee at MIT (and soon thereafter elected as a U.S. senator from Vermont), Georges Doriot, a professor of industrial administration at Harvard Business School and Karl Compton, President of MIT. In 1946, Flanders summarized the need for ARD as follows²:

As the years go by in our highly industrialized society, the funds available for new enterprise tend to concentrate in fiduciary hands. This in itself is a natural process, but it does make it more and more difficult, as time goes on,

¹ Permission to access and quote from the personal papers of Georges Doriot, president of ARD, was kindly granted by Richard J. Testa, Esq. As a publicly-listed company (starting in 1961 on the New York Stock Exchange), ARD also filed documents about its operations to the U.S. Securities and Exchange Commission.
² Copies of this and other historical documents referenced in this paper are on file with the author.
to finance new undertakings. The continued maintenance of prosperity and the continued increase in the general standard of living depend in a large measure in finding financial support for that comparatively small percentage of new ideas and developments which give promise of expanded production and employment and an increased standard of living for the American people. We cannot float along indefinitely on the enterprise and vision of preceding generations. To be confident that we are in an expanding, instead of a static or frozen economy, we must have a reasonably high birth rate of new undertakings.

Indeed, Doriot, president of ARD, believed that ARD was serving a role distinct from other financial institutions: “In recent months American Research has been erroneously compared to well-known, long-established investment companies. It should again be emphasized that American Research is a ‘venture’ or ‘risk capital’ enterprise. The Corporation does not invest in the ordinary sense. It creates. It risks. Results take more time and the expenses of its operation must be higher, but the potential for ultimate profits is much greater.” (ARD Annual Report, 1951). Years later, Doriot reflected on the circumstances that prompted ARD’s birth in a March 1961 speech to the Society of Chicago Security Analysts. He stated that ARD was formed out of the belief that research and development, which had been so important in America’s successful outcome in the Second World War, could be harnessed to provide an engine for economic growth and capital appreciation to shareholders if coupled with professional management.

ARD was not the only organization in 1946 with the goal of financing and helping new ventures commercialize R&D-based inventions, however. Several articles from the business press of that era (e.g., Business Week, 1946a, 1946b, 1946c; Barron’s, 1949; Fortune, 1949) describe the efforts of companies like Rockefeller Bros., J.H. Whitney, New Enterprises, Inc., and T. Mellon & Sons in similar initiatives. New Enterprises, Inc., for example, grew out of a group of “20-odd stockholders [who] were members of a similar organization before the war, but reorganized on a new basis this year. Stockholders are chiefly interested in new scientific and technological techniques with several commercial possibilities. They do not want to back merchandising or consumer services.” (Business Week, 1946b: 36).
For a more systematic history of the precursors of organized venture capital, see Florida and Samber (1994).

ARD was different from these other early VC firms on one dimension, however: in an effort to raise capital that would be more "patient" in its returns\(^3\), the ARD founders specified that at least half of the initial capital to fund the organization had to come from trusts and other institutions. To facilitate fund raising from institutions, ARD sought and received exemptions from the Securities and Exchange Commission\(^4\), which permitted ARD to hold more than 5% of the stock of a company and allowed any investment company to purchase up to 9.9% of ARD's shares (Fortune, 1952).

By 1947, ARD had raised $3.76M from the following initial stockholders: Investment trusts (nine companies holding 36% of ARD's stock), insurance companies (two companies, including John Hancock Mutual Life, holding 8%), educational institutions (four schools, including MIT, holding 6%), brokerage companies (twelve firms holding 7%), and individuals (209 individuals holding 43%). ARD required a $5,000 minimum investment for individual investors because the company wanted to select investors who could afford to make long term, high risk investments.

### 4.3 Evolving Practices at ARD

While Liles (1977) and to a lesser extent, Gompers (1994), provide a history of ARD based on public sources, my purpose is somewhat different. Through both public and private ARD documents, I assembled a database of characteristics of all 120 ARD portfolio companies during the period that ARD was independent, 1946-

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\(^3\) Indeed, Doriot wrote in an internal ARD memo dated April 12, 1961: "Part of ARD's reputation is built on the fact that we are not 'in and out' people. We go into a company to build. That means we plan to stay unless there are good reasons to sell and get out, for instance: (1) desirable merger, (2) loss of faith in management and inability to correct because of lack of control, or loss of faith in the field of interest at the time, (3) complete loss which is equivalent to [a] liquidation sale."
1973. In order to study temporal changes in ARD "policy" choices, I combine empirical analyses of these data with qualitative assessments of factors that may have contributed to those policy choices. The empirical analysis is presented in two stages. First, in sections 4.3.1 through 4.3.4, I examine quantitative and qualitative evidence for shifts in key policy variables over time. Second, in section 4.4, using multivariate regression analysis, I examine correlates of ARD's performance.

Using coarse (but meaningful) measures derived from historical ARD documents, the first part of the analysis presents simple t-tests of the hypothesis that key financing practices were followed with equal frequency in the first (1946-1960) and second (1961-1973) halves of ARD's investment history. While this time division of ARD's investment history is somewhat arbitrary, the analysis is done in the spirit of capturing broad changes in ARD financing practices over time. These practices, discussed in detail below, include choices relating to: (1) the affiliate's development stage, (2) the affiliate's industrial segment, (3) ARD's choice of affiliate by geographic location, and (4) ARD's method of financing the affiliate. Table 4.1 lists the measures used in the empirical analysis, together with their sources. The table also contains descriptive statistics and the results of t-tests for equality of means by time period. In each of the below sections, I describe the policy choice that ARD faced, whether my empirical measures detected any shift in the policy over time, qualitative evidence illuminating the policy choices over time, and finally, a brief comparison to the practice in modern-day VC organizations.

4.3.1 Development Stage

Although ARD was founded on the premise of the need for a new financial institution to fund early stage start-ups, a relatively small number of such investments were made in the first half of ARD's investment career. The variable, ARD INVESTED EARLY, is based on data drawn from a 1966 Doriot memo that classifies ARD affiliates' development stage for the time period 1946-65. Unfortunately, Doriot

\[\text{ARD had been incorporated as an investment company, which was regulated by the SEC through the}\]
did not document his criteria for such classifications. To classify the development stage of ARD investments made from 1966-73, I relied on an interview with then-ARD assistant vice president, Daniel Holland, who started working at ARD in 1969. While drawing on two different sources has obvious comparability limitations, I am not aware of a source of comprehensive ARD development stage information for the period 1946-73.\(^5\)

While 55\% of ARD’s investments in the later time period were in early stage ventures, only 21\% of the firm’s investments in 1946-60 were in such firms, a difference which is statistically significant. Because separating ARD’s investments into the first and second half time periods is somewhat arbitrary, I examined differences by five-year intervals and again found the same patterns. For example, ARD’s early stage investments ranged from a low of 14\% in 1951-55 to a high of 59\% in 1961-65.

What explains these temporal investment patterns in early stage ventures, particularly when ARD’s original mission was to fund young companies? First, the business press in the early 1950s expressed the sentiment that venture capital was regarded as an experiment which might be abandoned if the initial efforts failed. For example, Barron’s (1949) reported: “Designed to meet that need [of growth capital for small businesses], venture capital companies today number fewer than ten, and their total resources probably do not exceed $25M by very much...If they prove to be successful, their example may attract important investors in large numbers to the field of venture capital.” Fortune (1952) stated more bluntly: “ARD realized that if it failed, or did only passably, the experiment might not be repeated.” These legacy effects may have influenced Doriot’s choice of projects to fund in the first years of ARD’s operations. Learning effects of how to manage early stage investments may

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\(^5\) As a limited attempt to separate the time effects of ARD investments by development stage from the idiosyncratic individual effects of labeling an investment early stage, I did a t-test of means of the seven years before 1966 (data from Doriot) and the seven years following 1966 (data from Holland). The test does not reveal significant differences.
have been an important explanation for the subsequent rise in ARD’s investments in younger firms. This second explanation is consistent with Charles Waite’s (2000) account of Greylock’s initial reluctance to fund early stage start-ups, an explanation distinct from the potential legacy effect since Waite and fellow ARD investment officer William Elfers left ARD to form Greylock in 1965-66.

Fast forwarding to modern day VCs, the role of specialized knowledge and resources to develop companies of a given stage may have become even more important in determining the boundaries of the VC firm. For example, private equity firms appear to be specializing by stage of company, recognizing that competencies in financing and developing seed stage investments differ from those necessary to develop later stage ones, such as turnaround or “buyout” situations (Roberts, 1991; Gompers and Lerner, 1999). While comparing ARD’s record in seeding early stage companies to modern-day VC financing practices is difficult, in part due to defining what “early stage” means⁶, modern day VCs appear to be less diversified by development stage.

4.3.2 Industrial Specialization

A second ARD raison d’etre was to convert technological advances in the postwar era into commercialized products. To assess temporal changes in ARD funding to R&D-based affiliates, I gathered business description information from ARD annual reports to shareholders to code the variable, R&D INTENSIVE. This variable was set equal to one if the ARD affiliate company was engaged in one of the following “high-technology” industrial segments: earth sciences, chemicals, industrial & scientific equipment, electronics, or data processing/storage. ARD seemed to invest in a number of non-R&D intensive industries during certain periods, such as in food product investments (1946-50), professional services (1951-55 and 1961-65), and

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⁶ While data sources such as the Venture Economics collect information about VC investments by start-up stage, this information is self-reported by VC firms. As Gompers (1995) notes, there is no clear division among the definitions of each stage (in practice), so divisions should be interpreted as relative rather than absolute measures of firm development. In addition, this information may be biased over time as “early stage” investments are seen as more or less desirable.
education & media (1966-71). On the whole, however, according to my measure, ARD invested in a high percentage of R&D oriented projects across its life, with 73% of its investments in a high-tech sector.  

A t-test of differences in means by time period, however, suggests that ARD was more likely to invest in more R&D-intensive projects in the first half of its life.

This shift, while subtle, seems to be reflected in ARD’s annual reports. For example, Doriot wrote in the 1955 report that its industrial sector interests included: applied physics, electronics, nucleonics, chemistry, thermomechanics, instrumentation, and specialized equipment. By 1961, after having placed investments in the previous year in musical instruments and equipment rental, Doriot wrote: “Stockholders and friends are urged to be aware of ARD’s interests and to recommend situations which appear worthy of consideration...There is no single industry or group of industries into which ARD’s funds are directed.”

In addition to temporal shifts in technological opportunity, another external explanation for the reduced level of R&D-based investments may have been due to the reduced demand for technology IPOs as a result of downturns in the business cycle. As well, two internal factors could have contributed to the observed outcome. First, Doriot may have been interested in achieving a more diversified portfolio of investments. Secondly, with increased competition from other venture capital firms and other sources of capital for attractive technology-based deals, ARD may not have been able to invest in technology deals of a consistently high quality over time. In support of this view, at the same time that Doriot was publicly stating that technology-based ventures had been responsible for the lion’s share of ARD’s profits (in a 1961 speech to Chicago Security Analysts), ARD’s share of investments in R&D-based firms was decreasing. In an internal 1964 memo, Doriot complained that ARD officers were not exploring creative new ideas for investments, instead relying on “old knowledge” associated with a bygone era of opportunity. Furthermore, in an internal 1965 memo, Doriot expressed the view that because ARD officers did not

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7 Doriot’s industrial sector interests may have been influenced by student projects in his famous
feel "heavy responsibility" over the inflow of high quality projects, ARD was losing competitive ground. This suggests that ARD may not have wanted to reduce its share of R&D-based projects; rather the firm's reduced competitiveness for technology deals may have contributed to the observed outcome.

As in the movement of modern day VCs to specialize by stage of development, it appears that current VCs tend to specialize in high-tech segments, with investment professionals within firms sometimes concentrating on a single industrial sector. The trend to investing in industries with high R&D to sales ratios accords with Gompers' (1995) finding that VCs have designed mechanisms that are particularly well-suited to these types of investments. As well, by concentrating in particular industrial sectors, VCs can acquire "domain" knowledge and build important social relationships to assist their portfolio companies (a view consistent with the findings of the second chapter of this thesis). This industrial sector knowledge may be an important way for VCs to broker valuable strategic information between portfolio companies in related industrial and product segments.

4.3.3 Geographic Location

A third ARD financing practice was choosing which affiliates to back, in part based on their geographic location. To examine whether the geographic location of ARD's portfolio companies shifted over time, I constructed two dummy variables, MASSACHUSETTS LOCATED and "FAR" LOCATION. The latter is a variable equal to one if the affiliate was located in the western U.S. or abroad. This measure follows Lerner's (1995) interpretation, which suggests that active management is facilitated by VC geographic proximity to their portfolio companies. T-tests of time period differences in my measures indicate that ARD was more likely to invest in Massachusetts-located firms in the first half of its operating career, while investing in

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8 Manufacturing” course at Harvard Business School.
8 However, a simple pairwise correlation between ARD INVESTED EARLY and “FAR” LOCATION suggests the two variables are uncorrelated.
an affiliate “far” away was marginally more likely in the second half (significant at the 11% level).

The finding that ARD’s investments became progressively geographically dispersed over time may be more an artifact of Doriot’s interest in international operations and expansion of the venture capital model rather than changes in the level of active monitoring over time. As an example of Doriot’s interests, as early as 1950, Doriot established “regional committees” in Philadelphia and Providence, Rhode Island to identify potential investment opportunities. In addition, ARD expanded its set of affiliated VC companies to both Canada and Europe in 1962, and to Australia in 1972.

Qualitative evidence from the historical record seems to indicate that active management was a high priority to Doriot. Doriot and several other ARD officers typically joined the boards of their affiliate companies in order to actively participate in the managerial direction of the firm. A distinct feature of ARD’s post-investment practice in affiliates became known as the “Doriot style” of active investment. This style was a balance between active participation in an affiliate in ways which leveraged professional management and advice without overbearing the entrepreneur’s autonomy in decision-making.9 The “Doriot style” of VC management became popular with ARD spin-off VC firms, and proved to be a widely-diffused management practice at other VC firms, as well (Liles, 1977; Waite, 2000). Furthermore, the Doriot style accords with Hellman and Puri’s (2001) notion of contingent VC roles in which VCs provide business services such as recruiting when the affiliate is in a “good” state and use control in a “bad” state. From the very beginning, Doriot exercised corporate control when he deemed it necessary: “[With reference to Circo Products], for the three year period since this investment was made, the company has operated at approximately a break even basis. Since no substantial progress has been made toward retiring the debt, AR&D reached the
conclusion that top management should be replaced. In January 1950, AR&D acquired voting control through a recapitalization and installed a new operating head.” (ARD’s 1950 Annual Report). A 1967 Fortune article, however, reported that some critics faulted Doriot for not replacing top managers at some affiliate companies soon enough. Doriot is quoted in the article as indicating it was not ARD’s ordinary policy to replace the head of a company it had backed, and that he found the task of replacing top managers quite unpleasant.

Active post-investment involvement with portfolio companies was neither obvious nor universal in the 1950s. As a point of comparison, First Midwest Capital Corporation of Minneapolis, Minnesota was also an early venture capital organization\(^9\), having been founded in 1959. While First Midwest paralleled ARD in becoming a publicly-listed organization, the management styles of the two organizations were quite different. While Alan Ruvelson, the founder and president of First Midwest, did not actively intervene in his portfolio companies (personal communication with Ruvelson), Doriot actively monitored the progress of his companies and intervened, if necessary.

Doriot’s active participation was not confined to the board of directors meeting room. He kept log books on the portfolio companies, in one case even speculating on the effects of an entrepreneur’s marital problems on his productivity. Doriot made a note to hire a maid for this entrepreneur so that more time could be spent on the work of the company rather than doing work around the house. In addition, ARD actively engaged in staging investment rounds. In an undated internal ARD memorandum, Doriot commented on the importance of staged funding: “Any financing must be done or should be done in such a way as to make the next one less expensive to the company. In other words, there must have been an element of

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\(^9\) As Gerschenkron (1966: 14) notes, however, late 19\(^{th}\) century German banks “acquired a formidable degree of ascendancy over industrial enterprises, which extended far beyond the sphere of financial control into that of entrepreneurial and managerial decisions.” This indicates that ARD’s actions were with some measure of precedent.

\(^{10}\) First Midwest received one of the first two Small Business Investment Corporation (SBIC) licenses from the U.S. federal government. The SBIC program was a government initiative to provide equity-based capital to entrepreneurs. See Noone and Rubel (1970) for details and a history of the program.
progress, of success, before the next financing is necessary... There are many reasons why it is advisable for the new company to have a limited amount of capital at its disposal at the very start. One of the main reasons is that in the hands of an inexperienced person commitments of all types are often made quite recklessly and capital has a way of disappearing at a remarkable high rate of speed. At that time, being limited as to expenditures is a good form of training."

VC researchers have since done studies of the importance of staging financing rounds in order to reduce potential agency problems with entrepreneurs (Sahlman, 1990; Gompers, 1995). The practice is now nearly universal across modern-day VC organizations, as is active board of director participation by venture capitalists. In addition, for the most part, current VC firms’ investments tend to be rather local because geographic proximity facilitates both entrepreneurial monitoring (Lerner, 1995) and value-added services through the VC’s information network (Sorenson and Stuart, 2001).

### 4.3.4 Financing Method

A stream of research examining financial contract design choices to solve potential agency problems between entrepreneur and venture capitalist has attracted a good deal of academic interest (e.g., Admati and Pfieiderer, 1994; Hellman, 1998; Kaplan and Strömberg, 2000a). By looking at the correlation of financing design choices by ARD with characteristics proxying for potential agency problems of ARD portfolio companies, we should be able to observe whether ARD adjusted its financing methods to suit the situation. Moreover, we will be able to see whether there was any evidence of ARD “learning” effects in this regard over time. To set the stage for the empirical analysis, it will be useful to understand the state of financing method sophistication in the early 1950s. A Fortune article (1949) described the financing practices of an ARD peer: “Rockefeller Brothers invests only in established concerns with the nucleus of a sound management, and buys mostly common and convertible preferred stock (occasionally taking debentures).” Another Fortune article
(1952) reported on ARD's financing practices: "As a rule, ARD likes to invest some of its money in the form of notes or debentures, and the rest in voting stock to acquire part ownership [of the affiliate], usually 20-35%. Management fees are now a frequent part of the ARD package." An examination of the financing methods ARD used also reveals that convertible debt financings were relatively infrequent, as was taking preferred equity shares (most equity investments were in common stock).

From ARD's annual reports, I coded the method used to finance each of the ARD portfolio companies into either DEBT-ONLY or EQUITY-ONLY (with the excluded category as using both debt and equity financing). ARD used DEBT-ONLY instruments (which excludes those financings with warrants for equity participation) in 15% of its deals over the 1946-73 time period, while using EQUITY-ONLY instruments in 34% of the deals in that time frame. T-tests of means for both of these variables do not reveal any statistical differences between the first and second halves of ARD's operational history. However, because the form of financing may itself depend on affiliate characteristics, most notably the amount of uncertainty, a regression analysis controlling for these factors is appropriate. Table 4.2 presents multinomial logits, modeling ARD's decision as a choice between DEBT-ONLY, EQUITY-ONLY, and a combination of the two as the excluded choice. (4.2-1) presents a regression with two measures correlated with potential agency problems: ARD INVESTED EARLY and R&D INTENSIVE. The use of EQUITY-ONLY is not correlated with these measures of agency, while ARD INVESTED EARLY is correlated with DEBT-ONLY financing. These basic results are robust to controls for a third measure of agency, the geographic proximity of the portfolio company, as well as temporal effects, as captured in INVESTED FIRST HALF (see 4.2-2). Moreover, the estimated ARD INVESTED EARLY effect is large, with a discrete change in non-early investments to early investments associated with a 14% increase in the likelihood of using a debt-only financing instrument relative to using a debt and equity financing option.

11 These two measures of agency are standard in the literature (see Gompers and Lerner, 1999).
This finding is somewhat at odds with the following statement taken from ARD's 1961 annual report: "ARD has no specific formula for financing companies. Each investment opportunity is considered individually, and the form of the financing is dictated by the individual requirements of the situation." Ironically, it was a 1957 equity-only investment in Digital Equipment Corporation (DEC) which lifted the entire ARD portfolio to above-benchmark returns (Liles, 1977). The DEC financing will be discussed in more detail in the next section.

The positive correlation between ARD INVESTED EARLY and DEBT-ONLY suggests that ARD dealt with uncertainty (as proxied by early stage risk) by using debt. Modern day VCs, on the other hand, nearly universally use equity-based financings, even in early stage situations (Roberts, 1991; Kaplan and Strömberg, 2000a), and do not generally take management fees for value-added services to their portfolio companies. Moreover, the equity financings are overwhelmingly in the form of convertible preferred stock (Sahlman, 1990, Kaplan and Strömberg, 2000a). Three explanations may be important in accounting for the convergence over time in financing method. First, with increased sophistication of the contractual covenants between venture capitalist and entrepreneur, particularly in the control rights that the VC possesses, potential agency problems are reduced. Second, with increased VC specialization by industrial segment and development stage, information asymmetries between VC and entrepreneur are reduced, which may also act to facilitate equity-only financings. A final explanation is that an "equity culture" has taken hold of venture capitalists as a result of potential upside gains, a phenomenon Doriot himself pointed out in the 1971 ARD annual report.

4.4 ARD Performance

The financing practices described in the previous section can collectively be thought of as some of the defining characteristics of the venture capital form of organizing finance and development assistance to its affiliates. This sub-section
begins by empirically exploring whether these practices are correlated with a measure of ARD corporate performance. The next sub-section discusses the single largest contributor to ARD performance, the investment in Digital Equipment Corporation, and a concluding sub-section discusses the impact of ARD’s legal form on internal incentives and performance.

4.4.1 “Performance” Regressions

Did the four financing practices described in the previous section affect the corporate performance of ARD? To begin exploring this question, this section presents “performance” binary probit regressions. The measure of performance is a dummy variable, GAIN, which takes the value of one if ARD’s liquidation of the affiliate’s securities resulted in a gain, net of the costs of acquiring the securities. The data are from two sources: for liquidity events through 1973, I relied on the Doriot papers. To mitigate the problem of right censoring (liquidity events after 1973), I relied on interview data from Daniel Holland about the profitability of investments in the post-1966 era. Because ARD became a corporate division of Textron in 1972-73, obtaining the outcomes of ARD investments from the late 1960s would have been difficult without the Holland information.

The results are found in Table 4.3. The first column reveals that R&D INTENSIVE is positively correlated with GAIN in the bivariate case. The second column tests time period effects by examining five-year increments in ARD financing history. Because the excluded time period is 1966-73, the results suggest that relative to the final time period, earlier investments were more likely to result in a gain. The third column reveals that the R&D INTENSIVE result is robust to (and strengthened by) the time period dummies. Finally, (4.3-4) suggests that adding measures of development stage (ARD INVESTED EARLY) and location effects does not alter the basic R&D INTENSIVE result. In this last regression equation, MASSACHUSETTS LOCATED is also positively correlated with GAIN, as are the two time dummies for the 1951-60 period. This location result is consistent with at least two interpretations:
(1) ARD was better able to monitor and/or assist local affiliates, and (2) Massachusetts firms were of "higher quality" before and/or after the ARD investments. This second explanation raises a general caution about interpreting the results in Table 4.3: I do not have detailed controls for the quality of the projects. Nevertheless, the estimated economic effects from (4.3-4) are large, with discrete changes of R&D INTENSIVE and MASSACHUSETTS LOCATED from zero to one associated with 30% and 27% increases, respectively, in the probability of a GAIN at the mean of the other independent variables.

4.4.2 Investing in Digital Equipment Corporation

Examining ARD performance at the coarse level of a binary indicator variable for gains says nothing, of course, about the magnitudes of such gains (nor does it take into account inflation or risk-reward premia). ARD’s investment in DEC is a notable illustration. Given the strong MIT representation on ARD’s board, it is perhaps unsurprising that several of ARD’s initial investments were MIT-affiliated. For example, one of ARD’s earliest (and most profitable) investments was in High Voltage Engineering Corporation, a firm started by two MIT professors, and brought to ARD’s attention by MIT President, Karl Compton. High Voltage commercialized electrostatic generators used for, among other things, sterilizing equipment. Another early ARD investment was in MIT-originated Ionics, a company ARD funded in 1948 to commercialize a new membrane-ion exchange process from salt water.

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12 Karl Compton, the President of MIT, Edwin Gilliland, an MIT Professor of Chemical Engineering, and Jerome Hunsaker, head of the MIT departments of Mechanical and Aeronautical Engineering, were on ARD’s board of advisors. Horace Ford, the MIT Treasurer, was on the ARD board of directors.

13 The Doriot papers document the source of each of ARD’s affiliate companies, with 30% of them over the 1946-73 time period coming from ARD’s network of contacts (at MIT or HBS, ARD affiliates, and friends). Brokers (investment bankers, brokers, and other VC firms) meanwhile sourced 42% of ARD’s investments over the same time interval. As Table 4.1 indicates, these sources of affiliate firms did not differ statistically between the first and second halves of ARD’s operational life, nor are they significant predictors of GAIN or financing method. Then, as now, few VC investments seemed to originate from unsolicited sources.
In 1957, ARD invested in Digital Equipment Company (DEC), a start-up by two engineers from MIT's Lincoln Labs, Ken Olsen and Harlan Anderson. The 1957 ARD Annual Report stated that "DEC manufactures and sells transistorized digital 'building block' units, improved versions of research, development, and testing devices essential to manufacturers and designers of digital computer equipment." In exchange for what ended up to be 77% of DEC equity, the DEC founders received $70,000. The rest, of course, is history: eleven years later in 1968, ARD's initial investment (then diluted to a 17% stake) was worth $463.4M. Figure 4A plots ARD's net asset value with and without the DEC investment, suggesting that ARD's overall portfolio performance was heavily influenced by DEC. When ARD was acquired in 1972, ARD shareholders received a stock disbursement of ARD's remaining stake in DEC, as well as stock in the acquiring company, Textron. The circumstances that led to the Textron merger is interesting in its own right because it sheds light on ARD's declining competitiveness due to its organizational structure.

4.4.3 ARD's Diminishing Competitiveness

Because ARD was incorporated as a closed end fund and investment company, its operations were subject to SEC regulation under the Investment Company Act of 1940. Provisions of the 1940 Act prohibited investment organization personnel from taking equity stakes in either their investment company or their portfolio companies for conflict of interest reasons. These restrictions proved to be a severe constraint on ARD's competitiveness because ARD investment officers' financial incentives were dampened. A pair of internal Doriot memos from 1964 and 1965 foreshadowed the beginning of the end for ARD in this regard. These memos indicate that ARD had lost good projects due to weak financial incentives to the

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14 MIT tremendously influenced the fledgling company. Olsen (1983: 11) reflected: "We also brought some organizational ideas from MIT [to DEC]...We had so much confidence in MIT that we even followed the MIT operations manual. We took the same hours, we took the same vacations, we paid the same holidays."

15 Though MIT was an founding investor in ARD, the university (through Horace Ford) sold its stake after Karl Compton passed away in 1954 and so did not benefit directly from ARD's investment in DEC.
investment officers. Doriot blamed the lack of investment officer initiative, resulting from weak incentives, as contributing to the “aging process” at ARD. This accords with Waite’s (2000) experience when he was an ARD investment officer. He recalls placing a considerable amount of effort into assisting an ARD portfolio company, Optical Scanning, in the early 1960s. After managing to resurrect the start-up and move the company forward, the founder and president of the company gained $10M while Waite only received a $2000 bonus for his efforts.

Shortly thereafter, Waite and fellow ARD officer William Elfers left ARD in 1965-66 to form Greylock & Co., having raised private money from the Watson family (of IBM fame) and Sherman Fairchild (of Fairchild Semiconductors). Greylock was organized as a limited partnership, an innovation introduced by the California VC firm Davis & Rock in 1961 (Bygrave and Timmons, 1992) to allow VC general partners to participate through equity investments. Limited partnership are now the dominant form of organization in the modern-day VC industry, with over 80% of VCs adopting this legal structure (Sahlman, 1990; Gompers, 1994). Incidentally, founders of several second-generation VC firms were ex-ARD employees who adopted the “Doriot style” of trying to develop portfolio companies with “hands-on” management guidance. Besides Greylock, these firms include Boston Capital (started by Joseph Powell), Fidelity Ventures (started by Henry Hoagland and Samuel Bodman), Palmer (started by William Congelton and John Shane), and Morgan-Holland (started by James Morgan and Daniel Holland).

While 1971 marked ARD’s 25th year of operations, Doriot wrote in that year’s annual report that employee stock options had developed as a way of life and because ARD could not give options to its personnel, the company faced difficulty being competitive with partnerships. After considering various options including merging with other VC firms and reorganizing operations, Doriot decided in 1972 to undergo a merger and become the VC division of Textron.17

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16 For details on the partnership form of organization, see Sahlman (1990).
17 A final issue that relates to the form of VC organization but which may not have been directly responsible for ARD’s diminished competitiveness was its status as a publicly traded company. An
Reprise. The ARD case highlights the important practices associated with financing and developing start-ups. For example, ARD seemed to be most effective when it funded R&D-based organizations located in Massachusetts. By examining how and why ARD’s practices changed over time, we are able to gain some insight into the learning process associated with developing the venture capital financial institution.

4.5 Entry by Alternate Organizational Forms

4.5.1 Background

While the paper thus far has addressed the evolution of the VC form of organization (by tracing ARD’s practices over its existence), another important related area is the entry of new organizational forms in financing entrepreneurs at early stage ventures. These alternate forms have ranged from U.S. federal government efforts starting from the late 1950s, to more recent organized efforts such as angel groups and business incubators.

In order to study the question of what factors facilitated entry of alternate organizational forms in providing early stage financing to entrepreneurs, two definitions must be elaborated. First, I am referring to the function of external funding for early stage entrepreneurs, which excludes later stage private equity (e.g., leveraged buyouts). Secondly, I adopt the definition of organizational form put forth by Romanelli (1991): “... [T]he concept of organizational form refers to those characteristics of an organization that identify it as a distinct entity and, at the same time, classify it as a member of a group of similar organizations.” Each of the

issue left for further research is whether the concept of a public VC organization, because it has to make public disclosures about operations, is inherently at odds with the longer time horizon needed to successfully develop early stage, high-tech start-ups. How important was this effect, for example, in explaining the downturn in business incubators that went public in the late 1990s?
alternate organizational forms for early stage entrepreneurial finance has a distinct entity, yet the essential function across the forms is similar.

The thesis of this section is that entry of new organizational forms resulted from opportunities afforded by both the institutional structure of VC, as well as the business environment faced by VCs. The former explanation builds on a theme in the tradition of North’s work on institutional economics (North, 1990). The analysis begins by providing quantitative and qualitative evidence of two “puzzles” in VC finance that facilitated entry by new organizational forms: the concentrated nature of VC investments (section 4.5.2) and a funding “gap” for early stage ventures (section 4.5.3). A qualitative case study of the experience of funding cardiovascular medical device firms illustrates the funding gap in section 4.5.4. A final section exploring the persistence of these puzzles in VC finance concludes.

As in the spirit of the ARD case, this section is devoted to idea generation rather than definitive evidence on entry by new organizational forms. Accordingly, my aim is to provide preliminary evidence of one theory rather than a comprehensive study of the phenomenon.

4.5.2 Venture Capital Concentration

A first puzzle related to the VC form of entrepreneurial finance is that venture capital investments are more concentrated than we might expect, as measured by both industry and geographic location. After documenting this phenomenon, I discuss why this concentration might be important.

Figure 4B illustrates the disproportionate concentration of VC disbursements in a relatively small number of industrial segments. The time series plots are of Gini coefficients, a measure of relative concentration.\(^{18}\) The top two curves plot VC expenditures (by two digit SIC manufacturing sector) relative to two measures of technological opportunity (across the two digit SIC codes): patent counts and private

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\(^{18}\) The Gini coefficient ranges from 0 to 1, with increasing inequality suggested by higher values. Krugman (1991) and Audretsch and Feldman (1996) use this measure of relative concentration to study geographic concentration.
R&D expenditures. The top dashed line indicates that the cumulative distribution of VC disbursements is quite concentrated relative to the cumulative distribution of patents awarded by industrial sector, with Gini coefficient ranging from 0.34 to 0.55 over the 1965-1992 time period. Likewise, the solid line plots the Gini coefficient for VC disbursements relative to private R&D expenditures. The "U" shape suggests that since the 1975-79 time period, VC expenditures have become more concentrated.\(^\text{19}\)

As a comparison, the bottom dotted curve plots Gini coefficients for the relative concentration of patents to R&D expenditures by industry. The resulting curve serves as a useful benchmark: patent awards are not significantly more concentrated than the distribution of R&D expenditures.

Not only are VC investments concentrated into a relatively small number of industrial sectors, they are also concentrated geographically. Figure 4C, panel A plots VC expenditures in the top four VC markets: California, Massachusetts, New York, and Texas as a fraction of total VC expenditures. The fraction ranges from a low of about 46% to a high of 70% over the past twenty years. This geographic concentration of VC must be evaluated relative to the geographic concentration of inputs to be meaningful, of course. While the data are sparse and only available for select years, panel B of figure 4C reports Gini coefficients for the geographic concentration (at the U.S. state level of analysis) of VC disbursement relative to two measures of existing geographic location of technological opportunity: patents and industrial expenditures. The VC disbursement distribution is also compared to a measure of the location of human resources, the geographic distribution of Ph.D.-level scientists and engineers. These Gini coefficients indicate that the geographic distribution of VC funding is more concentrated than measures of the location of opportunity, albeit less so than VC industrial segment investments. Because geographic concentration is itself linked to industrial location, however, the results presented in figure 4C should not be surprising.

\(^{19}\) VC industry statistics for the pre-1975 period are not as reliable as the more recent data (see the discussion on VC data sources in Gompers and Lerner, 1999).
In each case of concentration, we might have expected competitive forces to dissipate concentration over time, as VCs would search for and fund opportunities in other industrial segments and in other geographic locations. Moreover, frictions such as high transportation costs do not appear to constrain financial capital movement.

Why is concentration important? By funding start-ups in a limited range of industrial segments, VCs may sacrifice both private and social value. For example, if VCs accept marginal projects in a favored industrial segment at the expense of funding infra-marginal projects in a different industrial segment (which would not have otherwise been funded), social welfare is clearly lowered.20

In addition, private value might be compromised by concentrated VC industrial segment investments if inter-industry knowledge flows are important in the innovative process (Scherer 1982; Rosenberg 1982; von Hippel 1988). Specifically, VCs who can serve as knowledge “brokers” across industries are not as valuable if their knowledge does not span a large range of industries, a recurrent theme throughout this dissertation.

Geographic concentration of VC may also be important from an equality point of view. Unequal economic development across geographic regions, particularly if the growth process in regions is subject to increasing returns and self-reinforcing cycles (Krugman, 1991), may call for public policy intervention. On the international level, if there are institutional reasons for localization of VC investments, this may have ramifications for government policy directed at establishing high-tech industries.

4.5.3 The Funding “Gap”

This section introduces a second puzzle in VC finance, the funding gap for early stage start-ups. After first briefly describing the funding gap and discussing its importance, I present qualitative evidence of the funding shortfall to early stage entrepreneurs in one high tech segment, the cardiovascular medical device industry.

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20 For example, during 1999, a plethora of business-to-business (B2B) e-commerce sites to build online exchanges in the same, or similar, industrial segments were funded (e.g., USA Today, 2000).
Existence of the funding gap. Even as venture capital disbursements have grown throughout the 1990s, the proportion of funds invested into early stage companies by private entities has decreased over time. Figure 4D (panel A) documents this phenomenon by plotting the proportion of early stage disbursements to total VC expenditures from 1980 through 1999. In this time interval, the fraction of early stage funds has ranged from a high of about 45% in 1981 to a low of about 23% in 1999. Aside from a jump in early stage investment in 1993, the trend is downward sloping. These data are taken from the industry consultants, Venture Economics, who define the early stages of new venture development and investment as follows at their web site:

Seed Stage – [I]nvestments…involving portfolio companies which have not yet fully established commercial operations, and may also involve continued research and product development.

First Stage – The first round of financing following a company's startup phase that involves an institutional VC fund…[F]or companies' whose product(s) are either in development or commercially available.

Note, however, that these definitions of development stages have probably not been constant over time. The stylized fact, then, is that external funds are available to entrepreneurs for both the very early stage of venture development21 (through angels) and the later stage (through VCs and corporate VCs), leaving a “funding gap” for early stage companies. This fact is puzzling because competitive forces in the supply of entrepreneurial finance should result in capital supply for companies of all stages. The funding gap is even more puzzling given the fact that relatively large returns are possible through early stage investment (Venture Economics, 1988a).

Importance of the funding gap. Paradoxically, VCs seem to rely on other institutions to develop and fund early stage start-ups at the same time that a high
quality pool of start-ups is critical for long term VC success. If venture capital firms are themselves an important institution of funding and developing innovative start-ups (Kortum and Lerner, 2000), and productive, leading edge technology start-ups are critical for national competitive advantage (Roberts, 1991; Bhide, 2000), then examining the causes of the funding gap will also be important.

An institution supporting early stage start-ups in the U.S. has been federal financing programs subsidizing early stage R&D.22 Because knowledge spillovers are thought to accompany early stage start-ups (the value of which is not fully captured by the investing firm), proponents of these public programs suggest a public good rationale for these subsidizes. Figure 4D (panel B) shows the growth of dollar values for U.S. public programs targeted at R&D for small businesses over time. At times, these public expenditures have either grown faster than their private sector counterparts, or have increased (year-on-year) compared to contractions in the available private sector early stage capital. Incidentally, many of the public policy initiatives around the world are aimed at this funding gap for early stage capital (OECD, 1995) due to the combination of liquidity constraints, uncertainty and asymmetric information at this stage of start-up development (Gompers and Lerner, 1999).

The goal of this section is not to evaluate public programs or private investments in R&D and new firm development. Rather, it is to understand the drivers of entry of organizational form in providing capital to start-ups. To the extent that institutional structures circumscribe the ability of organizational forms to assist in start-up development, a deeper understanding of the problems each form solves will be important in understanding the system of institutions involved in start-up financing and development.

21 Funds from friends, family, and credit card debt are commonly deployed in the early stages of a start-up (Roberts, 1991). In addition, while individual business angels are a heterogeneous group, they collectively represent an important source of financing for small firms (Freear and Wetzel, 1990; Freear, Sohl and Wetzel, 1994), though reliable data is difficult to find due to the private nature of this investment (Fenn, Liang and Prowse, 1998).

22 See Noone and Rubel (1970), Lerner (1999a), Wallsten (2000), and references therein for a description of these federal government initiatives.
4.5.4 Funding U.S. Cardiovascular Medical Device Start-ups

Making strong conclusions about the funding gap based on figure 4D is problematic, however. Specifically, establishing an appropriate benchmark for interpreting figure 4D is difficult, both because the counterfactual of what would have happened had alternate organizational forms been established is difficult, as is identifying the sample of companies that did not get funded (a censoring problem). Even less aggregated data, such as figure 4E which plots the percentage of early stage VC funds devoted to medical device start-ups, is not overly illuminating when looking for evidence of the existence of a funding gap. This results from the exclusion of non-VC funding sources. The lack of reliable and systematic data sources on non-VC early stage financing is an important reason that a quantitative study of a funding gap is difficult. Consequently, I now examine qualitative evidence of financing start-ups over time in one high-tech industry, cardiovascular medical devices (CMD), through a field-based case study. The findings suggest a VC funding gap for startups in the CMD industry and that the gap is related to the institutional structure of venture capital.

**Background.** The CMD industry is an attractive empirical setting to examine the phenomenon at hand both because of the coincident development of the industry with successive waves of organizational forms of entrepreneurial finance and because of the high level of start-up activity in the CMD industry.\(^{23}\) About 72% of the firms in the industry have fewer than 50 people, with an additional 24% between 50 and 500 employees (National Academy of Engineering, 1998). Indeed, a large percentage of R&D-intensive\(^{24}\), entrepreneurial firms characterize the medical device industry, as “growth in medical devices apparently occurred more by the addition of new companies than by expansion of old ones.” (USOTA, 1984: 7). The rapid rate of entry

\(^{23}\) I classify cardiovascular medical devices broadly: scientific instruments addressing cardiovascular disease.

\(^{24}\) R&D spending as a percentage of sales in this industry, at 8%, is second only to the pharmaceutical industry (NAE, 1998).
in this industry suggests an important role for financing organizations to support R&D activities.\textsuperscript{25}

The remainder of this section relies on suggestive field study-based evidence of the funding gap and its relation to the evolution of organizational form in provisioning finance to entrepreneurs. In accord with the geographic distribution of CMD start-ups (NAE, 1998), the case studies focus on a small number of key innovators in California, supplemented with a more limited investigation of such individuals in Minnesota.

**Methodology.** To select subjects for my field study in California, I relied on contacts made through the Stanford University Medical Device Network, an undertaking with strong links to the Stanford Medical Center and the Stanford engineering department. This organization maintains a database which contains profile and contact information for prominent academic scientists, industrial executives, and venture capitalists involved in, among other medical device subfields, the cardiovascular medical device industry in northern California.\textsuperscript{26} In Minnesota, after preliminary investigation, I made contact with the Minnesota Historical Society’s Oral History project on that state’s medical device industry.\textsuperscript{27} This project aimed to capture an oral history of the key individuals responsible for developing the state’s medical device industry. While the number of interviewees in this study is limited (see Table 4.4 for a list), they collectively represent some of the most important innovators and financiers in the development of the industry. Information from these primary sources underpins the discussion in the remainder of this section.

\textsuperscript{25} The high rate of R&D investment seems to reflect the rapid pace of innovation and the short product life cycle in the industry, coupled with less stringent regulatory requirements than, for example, the pharmaceutical industry (USOTA, 1984).

\textsuperscript{26} The Stanford Medical Device Network’s website reports that over 170 medical device firms are within an hour’s drive of Stanford University. The geographic concentration of high-tech firms may be related to private firms locating near university research centers and hospitals in an effort to capture knowledge spillovers from academic universities and hospitals (Rosenberg, 1992; Jaffe, Trajtenberg, and Henderson, 1993).

\textsuperscript{27} Interview transcripts are used with the permission of the Minnesota Historical Society.
CMD funding in the pre-1975 period. In the years before venture capital was widely available for the California CMD industry, innovation tended to be financed from friends and family or angel investors. The CMD industry in California can be traced back to the 1960s, during which time an invention by a surgeon, Thomas Fogarty, was particularly important. Developed while he was still a medical student, the Fogarty Catheter revolutionized surgical procedures to remove blood clots. To commercialize his catheter, Fogarty licensed the technology to a Southern California company, Edwards Labs. Fogarty also helped found some of the early start-ups in the CMD industry in the 1960s and 1970s including Bentley Labs (to develop a disposable device to artificially oxygenate blood) and Hancock Labs (to commercialize a tissue heart valve). These two start-ups were financed out-of-pocket or through friends, family, and angel investors (personal communication with Tom Fogarty).

The early stage financing experience of two well-known Minneapolis-based CMD entrepreneurs in the pre-1975 era was similar. Earl Bakken, together with fellow University of Minnesota graduate student, Palmer Hermansley, started Medtronic Corporation in 1949. The company made innovations in cardiac pacemakers and defibrillators. Medtronic’s funding initially came through selling debentures, primarily to friends of the founders. Medtronic was turned down for funding by several VCs in the early 1960s, including Alan Ruvelson at First Midwest Capital Corporation. Ruvelson thought at the time that Medtronic had “a terrible operating statement and a balance sheet and a lot of downside risk.”

28 In this procedure, a catheter (a tube inserted into a patient that provides a passage for a medical device) is inserted through a small incision in the artery downstream from a thromboemboli, a blood clot. The surgeon threads the catheter through the clogged artery beyond the clot, inflates a balloon, and then drags the clot down the artery and out through the incision. Fogarty’s invention, patented in 1963, earned him the Lemelson-MIT Prize for innovation in the year 2000. The Fogarty catheter is the grandfather of a whole class of surgical instruments used in “minimally-invasive” procedures. These instruments enable surgeons to reach specific areas of the body by way of blood vessels and perform targeted treatments (The Country Almanac, 1996).

29 The technology for Edwards Labs originated from a University of Oregon inventor, Lowell Edwards, who had moved his company to California due to the state’s favorable tax environment. Fogarty may have decided to license his technology to Edwards Labs because he did his medical training at the University of Oregon.
communication with Ruvelson). Medtronic ended up taking its first professional round of financing from a small investment finance company, CIE, which received two seats on the company’s board in exchange for several thousand dollars in the mid 1960s.

A second important CMD entrepreneur in Minnesota was an ex-Medtronic employee, Manny Villafana, who commercialized an entirely hermetically sealed pacemaker using a lithium ion battery by founding Cardiac Pacemakers, Inc. (CPI). As an unproven entrepreneur in the early 1970s, Villafana had difficulty financing CPI. He finally met a local Minneapolis banker, Chris Hallum, who agreed to invest $450,000 if Villafana could raise $50,000. After great difficulty raising his portion from friends and family, Villafana successfully secured financing and started up the company in 1972 (Minnesota Oral History Project). Villafana subsequently went on to found another CMD venture, St. Jude Medical. The experience of the profiled entrepreneurs in California and Minnesota reveal the importance of informal funding, often from friends, family, and angel investors for initial seed capital for these ventures started before the mid-1970s. As well, informal funding appears to be important for the early stage, regardless of time period (see Roberts, 1991).

**VC funding for CMD finds since the late 1970s.** With the development of the venture capital industry in Silicon Valley, VC funds became an increasingly important source of capital to CMD entrepreneurs in the second half of the 1970s. While most of the early important companies in the CMD industry were located in southern California, the growing Silicon Valley-based VCs started attracting CMD entrepreneurs. Consequently, according to David Chonette, former president of Edwards Labs at the time that the company licensed the Fogarty catheter, and a venture capitalist at Brentwood Ventures since 1987, Silicon Valley quickly became the innovative center of the CMD industry.

Advanced Cardiovascular Systems (ACS), which produced balloon angioplasty catheter systems, was incorporated in 1979 and located in Silicon Valley. The company was co-founded by surgeon-entrepreneur John Simpson and ex-Kaiser
Healthcare executive Ray Williams. Williams, as founding CEO, raised $1.2M from angels and his own savings because the company had difficulty raising start-up capital from VCs initially. In the early years of California venture capital, medical device firms appeared to have difficulty attracting venture investment until after the proof-of-concept stage (personal communications with Williams). Eventually Williams did raise venture money following the proof of concept stage, and Eli Lilly subsequently acquired the company in 1984 for $126M in stock.\(^{30}\)

**Newer organizational forms: incubators and angel groups.** Business incubators, defined as “any organization that helps start-ups develop in an accelerated fashion by providing them with a bundle of services, such as physical space, capital, coaching, common services, and networking connections” (Hansen, Nohria, and Berger, 2000: 5), specialize in “hatching” early stage firms. While the surge in incubator organizations has largely taken place in the 1990s, the concept is not new in the CMD industry.

After initially licensing his technologies to established companies, Tom Fogarty started forming companies around his inventions, primarily because too many of his licensed technologies were resulting in failed products—and the technologies would revert back to him (Longman, 1996). Fogarty established his own research, development, and engineering group, Fogarty Engineering, in 1980 to facilitate the start-up process. The engineering group began to look like a business incubator as it transitioned from employing a few part-time graduate students from Stanford University to employing full time engineers. The group added equipment necessary to construct prototypes, and eventually hired a full time employee to address regulatory approval issues that the medical devices might face. Since the

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\(^{30}\) Incidentally, through bundling ACS together with other CMD firms it had acquired, Lilly spun off Guidant Corporation in 1994. ACS itself produced no fewer than 11 spin-off companies (personal communication with Williams). The first (and perhaps most important) was Devices for Vascular Intervention (DVI), a firm co-founded by Fogarty and Simpson. DVI was acquired by Eli Lilly in 1989, and was also packaged into the Guidant spinout. According to Alan Will, CEO of DVI, the company left an important legacy to the Silicon Valley labor market: no fewer than 13 Silicon Valley area CEOs or presidents of medical device firms were former employees of DVI (personal communication with Will).
group’s inception, Fogarty Engineering has spawned approximately 20 devices and has helped start 10 companies, all of which involve the minimally invasive diagnosis and therapy theme.

A more recent business incubator started in mid-1998 by Alan Will, the ex-CEO of Devices for Vascular Intervention and AneuRx, is the “Foundry.” The incubator helps entrepreneurs develop intellectual property as well as technical aspects of their technologies at the seed stage to better prepare the start-up for venture-backed financing in a second round of investment. This organizational form appears to be an effort to backwards integrate venture capital into technology development, from which a viable venture-backed startup can be formed. Indeed, Alan Will enlisted two prominent venture capital firms\(^{31}\) to bankroll his operation in exchange for the first opportunity to back technologies coming out of the Foundry. This behavior by the VCs might be interpreted as recognition that the incubator is involved in a different, yet complementary, phase of new enterprise development from traditional VCs.

While angel syndicates, like individual angel investors, tend to concentrate on early stage investments, angel groups seem to serve several additional functions. First, this form of organization decreases search costs for entrepreneurs seeking private financing, as they only have to locate one organization to potentially access the resources of many angel investors. Second, angel syndicates both lower the search cost for angels willing to make investments and diversify the angel’s portfolio of investments. The latter results because individual angels may not be able to adequately evaluate some investment opportunities.\(^{32}\)

The Silicon Valley-based Band of Angels, for example, has been inviting three entrepreneurs to its once-a-month dinner to introduce their business plans since the group’s start in 1996.\(^{33}\) Entrepreneurs are not allowed to make their pitch unless

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\(^{31}\) Each VC firm has a 4% stake in the Foundry investment fund. In order to attract the VCs, Will gave them right of first refusal to fund subsequent rounds for the technologies incubated at the Foundry.

\(^{32}\) Due to its traditional lack of organization, individual angel investors probably miss financing opportunities or discover ill-suited matches (Coveney and Moore, 1998).

\(^{33}\) The Boston-based Common Angels adopts a similar scheme for its monthly breakfast meeting.
one of the members of the Band of Angels has already pre-screened and “champions”
the entrepreneur by agreeing to serve on the board of directors of the start-up, if
necessary. Investments by individuals in the Band are voluntary, but individuals who
invest typically contribute approximately $50,000 to the financing package (funded
entrepreneurs average approximately $0.7M from the Band).\textsuperscript{34}

Both Tom Fogarty, founder of over 30 companies, eight of which were taken
public, and Ray Williams, co-founder of Advanced Cardiovascular Systems are
members of the Band of Angels (Table 4.5 lists some of Fogarty’s prominent start-
ups).

\textit{Reprise.} This case study of the cardiovascular medical device industry
introduces entry of various organizational forms of entrepreneurial finance in funding
CMD start-ups over time. The case suggested that venture capitalists hesitated in
funding CMD start-ups at the proof of concept stage, a qualitative indicator of the
funding gap over time. The CMD case study accords with prominent venture capital
practitioners such as Morgenthaler (2000), who suggests that in his experience, VCs
specialize in financing commercial rather than technical risk. Both the concentrated
nature of VC investments and the funding gap in venture funding represent puzzles
since the supply of entrepreneurial finance appears to be competitive. The next
section therefore discusses two explanations for the persistence of these puzzles.

4.5.5 \textit{Tentative Explanations}

Two explanations for the dual puzzles are presented in this section. The first
stresses the structure of the institution of venture capital itself, that VC as an
organizational form has a competitive advantage over other forms in financing and
developing certain “kinds” of start-ups. The second explanation highlights the
business environment as a key factor, specifically that VCs avoid funding certain
kinds of start-ups as a result of weak appropriability conditions.

\textsuperscript{34} See Darwall and Roberts (1999) for more details about the Band of Angels.
**VC structure-based explanations.** The first explanation is based on the notion that VCs specialize in funding start-ups which are well suited to the mechanisms VCs have developed. In addressing the concentration of VC investments in a relatively small number of industrial sectors, Gompers (1995) notes that VC investments tend to be in high-tech industries because these industries have a higher share of intangible assets which can be addressed by VC monitoring mechanisms. More specifically, Gompers finds that firms with higher industry R&D intensities are associated with shorter time duration between funding rounds, suggesting that monitoring intensity is highest for high-tech firms.\(^{35}\) As well, as discussed in the ARD case, a second mechanism that allows VCs to invest in industries with severe asymmetric information is active participation on start-ups' boards of directors (Lerner, 1995; Hellman and Puri, 2001).

While observed geographic concentration of VC investments is probably not independent of industrial concentration, VC active corporate board participation is facilitated by geographic proximity. Lerner (1995) finds that VCs participate on corporate boards more frequently when the need for oversight is greatest, between transitioning CEOs. Furthermore, Lerner finds in this study that VC’s closest in geographic proximity to its portfolio company are more likely to join the board of directors, a finding consistent with the claim that the cost of providing start-up oversight depends on geographic distance. VCs may also co-locate with their portfolio companies to provide resources and connections associated with the VC’s information and social network. Because the scope of the VC’s social network is more costly to maintain across long distances, the bounded nature of social networks may contribute to the observed clustering effect (Sorenson and Stuart, 2001).

VC mechanisms may also help resolve the funding gap puzzle. In particular, intensive monitoring for early stage ventures may require “too much” (and probably different) venture capitalist attention. As VC funds have increased in size faster than the supply of capable professional venture capitalists, VCs have had to invest larger

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\(^{35}\) In his study, Gompers (1995) does not find statistical differences in duration between financing
amounts of capital into each start-up. This is a result of VCs constrained to participate in a limited number of boards of directors (due to both internal policy and covenants with the VC’s limited partners). Consequently, VCs invest in companies further along in their development, which need larger capital infusions. In order to acquire a sufficient equity stake in a more developed start-up to justify corporate control, VCs must spend more money to acquire equity in each one. Happily, this allows VC firms to invest their larger funds while keeping individual venture capitalists on a reasonable number of corporate boards.

**Appropriability-based explanations.** A second explanation for the puzzles is based on differences in appropriation levels. Observed clustering of VC investments by industrial sector may be due to inter-industry differences in the ability of start-ups to appropriate the commercial potential of their innovations. VCs may therefore be investing in areas of the economy where appropriability conditions for start-ups are favorable. Empirically testing this proposition has been difficult since most data sets of inter-industry differences in appropriability conditions (e.g., Levin, et al., 1987) have focused on larger, more established firms. Gans and Stern (2000b), however, suggest an empirical test for the relative importance of imperfections in the capital market (such as difficulty in the contracting environment leading to capital constraints) and imperfections in the product market (such as difficulty in appropriating returns from innovation) in explaining R&D investment concentration for a sample of research-oriented start-ups. While their sample size is limited, these researchers find empirical evidence for the relative importance of variation in appropriability in explaining the concentrated nature of R&D investment by industrial segment. As for geographic concentration, I am not aware of studies that directly rounds between early and later stage start-ups, however.
relate variance in the intellectual property (IP) environment (perhaps across countries which have different IP policies) to geographic clustering of VC investments, though Porter and Stern (2001) discuss related issues.

The role of formal IP protection may also be important in explaining VC investment patterns by development stage. Early stage companies may not have IP protection, and as a result, entrepreneurs may be unwilling to engage in negotiations with VCs (anecdotal evidence suggests that some entrepreneurs may fear that VCs might “steal” their ideas, despite non-disclosure agreements e.g., The Sunday Times – London [2000]). As well, VCs may be unwilling to invest in start-ups without formal IP protection (Gans and Stern, 2000b). Unfortunately, there is limited empirical evidence in the academic literature on the role of IP in contributing to the funding gap. Kaplan and Strömberg (2000b), however, present intriguing descriptive evidence on the phenomenon based on analysis of investment memoranda written by VCs on perceived opportunities and risks associated with investing in 42 portfolio companies (18 of which are pre-revenue, and therefore classified as early stage) by 10 VC partnerships. These authors find that their sample of memoranda contained over twice as many theses of favorable start-up competitive positioning (including the presence of IP) relative to theses of contractual structure that limits VC risk (which can be thought of as a proxy for agency risk). Similar descriptive statistics hold on the perceived risks of investment: the memoranda contained nearly twice as many mentions of a risky competitive position (inter alia, that “patent protection alone might not provide enough barriers to entry”) than the risk that it would be costly to monitor investments. While this study in no sense provides conclusive evidence for

36 Lerner (1999b) notes that the supply of venture capitalists skilled at monitoring and active management is somewhat limited. Furthermore, he contends that the prospect of hiring more associates, and therefore sharing management fees constrains the number of personnel at VC organizations. An alternate explanation for the number of VC personnel results from the form of decision making at VC firms. An increased number of decision makers may alter the relative efficiency of using one model of decision making (i.e., by committee) rather than another (i.e., by hierarchy). The choice of decision-making model has implications for the quality of decision made, as well as the optimal number of decision makers (Sah and Stiglitz; 1986, 1988).
the relative importance of expropriation over information and agency problems, it suggests potentially fruitful directions for future research.

4.6 Discussion

In this preliminary study, I presented a case study of American Research & Development to illustrate the evolution of VC practices (at a single firm), and used a combination of quantitative and qualitative evidence, including a case study of financing cardiovascular medical device start-ups, to explore the entry of alternative organizational forms in providing entrepreneurial finance. Two explanations, one rooted in the institutional structure of VC, the other grounded in the appropriability environment, are offered for the observation that VC investments both leave a funding gap for early-stage start-ups and are concentrated industrially and geographically. In either case, alternate organizational forms seem to have taken the opportunity to fund start-ups in the areas VCs have neglected. At the same time, the alternative organizations do not seem to replace the VC form of organization. Therefore, the various alternate organizational forms appear to form a complementary system of financial institutions for start-up funding and development. After discussing limitations to the study, I suggest some potential avenues for future research.

Limitations. In the first half of the study, because ARD was only a single company, we must be cautious about generalizing from the case, especially given the coarse measures used in the empirical analysis. In addition, due to the nature of the archival evidence, we must be wary of making strong conclusions about internal policy changes based on the historical documents. In the second half of the study, because the evidence is primarily qualitative, causal interpretations of the factors that enabled entry of alternative organizational forms cannot be made. In addition, alternative explanations are also difficult to rule out based on the evidence presented. Moreover it is difficult to generalize about a funding gap for early stage entrepreneurs
based on a case study of a single industry. As previously discussed, however, systematic quantitative studies have been elusive due to data constraints. Finally, I am not able to address the timing of new organizational form arrival. This is a difficult matter to tackle, however, due to the likely complex process of organizational innovation.

**Future Research.** This exploratory study raises several business and public policy issues I intend to pursue in future research. First, because the study of the evolution of organizational practices at VC organizations is incomplete, investigation into other (early) VC companies and innovations they pioneered is warranted to better understand the movement to converging VC practices. This will be done in the spirit of the ARD case presented in this chapter—collecting historical evidence for the purpose of examining learning effects and understanding the economic and social functions of organizational innovations. Second, is it possible to construct an empirical study with testable hypotheses about the funding gap? Doing so will require an empirical setting in which data about the appropriate counterfactual financing options for early stage funding can be collected. Such an effort, while difficult, would be interesting because the funding gap forms an important basis for public policy. In future research, I plan to systematically collect data on start-ups in a single industry, cardiovascular medical devices, to empirically explore the funding gap. Third, are “cross-breeds” of organizational forms sustainable? Charles River Ventures, a prominent New England VC, for example, launched CRVelocity, a division within Charles River to perform incubator-like services (*New York Times*, 2000). More generally, this issue brings up questions about the organizational boundaries of the venture capital firm such as the relationship between forms of organization in providing entrepreneurial finance and the strategy and performance of the portfolio company. In doing research to address this set of issues, I expect to pay careful attention to the economic and social mechanisms of the organizational forms which are associated with performance differentials at start-up firms.
Figure 4A. American Research and Development Net Asset Value, 1946-1971

Figure 4B. Concentration of VC Disbursements, Private R&D Expenditures, and Patents for the U.S. Manufacturing Sector, 1965-92

Source: author's calculations based on data from Kortum and Lerner (2000).
Panel A. Geographic Concentration of VC Disbursements in Top Four Markets, 1980-1999

Panel B. Concentration of VC Disbursements vs. Technological Opportunity by U.S. States, Select Years

<table>
<thead>
<tr>
<th>YEAR</th>
<th>VC-PATENTS GINI COEFF.</th>
<th>VC-R&amp;D EXPENDITURES</th>
<th>VC-SCIENTISTS &amp; ENGINEERS GINI COEFF.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1980</td>
<td>0.189</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>0.251</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td></td>
<td>0.152</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>0.237</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1993</td>
<td></td>
<td>0.309</td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>0.235</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td>0.182</td>
<td></td>
</tr>
<tr>
<td>1999</td>
<td>0.218</td>
<td></td>
<td>0.275</td>
</tr>
</tbody>
</table>

Source: Calculations based on data from Venture Economics, U.S. Patent and Trademark Office, and National Science Foundation data.
Figure 4D.
Panel A. VC Disbursements: Early Stage vs. Total, 1980-1999

Panel B. Public vs. Private Early Stage Funds for High-Tech Start-ups, 1983-1997

Source: Venture Economics and the Small Business Administration. Note: Public funds include funding from the Small Business Innovative Research program, the Advanced Technology Program, and the technology-based investments made by the Small Business Investment Corporation program.
Figure 4E.
Early Stage VC Investments in the U.S. Medical Device Industry, 1980-99

Source: Venture Economics and author's calculations.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>BROKER SOURCED</td>
<td>Dummy = 1 if ARD sourced the affiliate company through inv. banker or broker</td>
<td>0.417</td>
<td>0.495</td>
<td>0.503</td>
<td>0.327</td>
</tr>
<tr>
<td>ARD SOURCED</td>
<td>Dummy = 1 if ARD sourced the affiliate through a personal contact</td>
<td>0.300</td>
<td>0.460</td>
<td>0.481</td>
<td>0.231</td>
</tr>
<tr>
<td>ARD INVESTED EARLY*</td>
<td>Dummy = 1 if ARD created or invested early in the portfolio company</td>
<td>0.348</td>
<td>0.478</td>
<td>0.206</td>
<td>0.407</td>
</tr>
<tr>
<td>R&amp;D INTENSIVE*</td>
<td>Dummy = 1 if portfolio company was in one of the following industries: earth sciences, chemicals, industrial &amp; scientific equipment, electronics, or data processing/storage</td>
<td>0.733</td>
<td>0.444</td>
<td>0.809</td>
<td>0.396</td>
</tr>
<tr>
<td>MASS. LOCATION*</td>
<td>Dummy = 1 if the portfolio company was located in Massachusetts</td>
<td>0.275</td>
<td>0.448</td>
<td>0.368</td>
<td>0.486</td>
</tr>
<tr>
<td>&quot;FAR&quot; LOCATION</td>
<td>Dummy = 1 if the portfolio company was located in either the U.S. west coast or overseas</td>
<td>0.133</td>
<td>0.341</td>
<td>0.059</td>
<td>0.237</td>
</tr>
<tr>
<td>INVESTED FIRST HALF</td>
<td>Dummy = 1 if ARD invested in the portfolio company between 1946-1960</td>
<td>0.566</td>
<td>0.498</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>EQUITY ONLY</td>
<td>Dummy = 1 if ARD financed the portfolio company through equity only</td>
<td>0.342</td>
<td>0.476</td>
<td>0.368</td>
<td>0.486</td>
</tr>
<tr>
<td>DEBT ONLY</td>
<td>Dummy = 1 if ARD financed the portfolio company through debt only</td>
<td>0.150</td>
<td>0.359</td>
<td>0.147</td>
<td>0.356</td>
</tr>
<tr>
<td>GAIN*</td>
<td>Dummy = 1 if liquidation of the portfolio company resulted in a gain</td>
<td>0.615</td>
<td>0.489</td>
<td>0.731</td>
<td>0.448</td>
</tr>
</tbody>
</table>

* indicates t-test of difference of means between the (1946-60) and (1961-1973) time periods is significant at the 5% level.
**TABLE 4.2**  
ARD FINANCING METHOD  
MULTINOMIAL LOGITS

<table>
<thead>
<tr>
<th>Dependent Variable = DEBT-ONLY or EQUITY-ONLY</th>
</tr>
</thead>
<tbody>
<tr>
<td>(DEFAULT = DEBT &amp; EQUITY)</td>
</tr>
</tbody>
</table>

* N = 115 observations *

<table>
<thead>
<tr>
<th></th>
<th>(4.2-1)</th>
<th>(4.2-2)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DEBT-ONLY = 1</td>
<td>EQUITY-ONLY = 1</td>
</tr>
<tr>
<td></td>
<td>DEBT-ONLY = 1</td>
<td>EQUITY-ONLY = 1</td>
</tr>
<tr>
<td>ARD INVESTED EEARLY</td>
<td>1.100 (0.558)</td>
<td>0.148 (0.447)</td>
</tr>
<tr>
<td>R&amp;D INTENSIVE</td>
<td>-0.436 (0.632)</td>
<td>-0.482 (0.475)</td>
</tr>
<tr>
<td>MASSACHUSETTS LOCATED</td>
<td>-0.007 (0.685)</td>
<td>0.485 (0.482)</td>
</tr>
<tr>
<td>&quot;FAR&quot; LOCATION</td>
<td>0.311 (0.919)</td>
<td>-0.233 (0.773)</td>
</tr>
<tr>
<td>INVESTED FIRST HALF</td>
<td>0.525 (0.672)</td>
<td>0.239 (0.481)</td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-1.288 (0.594)</td>
<td>-0.40 (0.426)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-1.721 (0.816)</td>
</tr>
<tr>
<td>Log Likelihood</td>
<td>-113.069</td>
<td>-111.782</td>
</tr>
</tbody>
</table>
TABLE 4.3
ARD “PERFORMANCE” PROBITS

<table>
<thead>
<tr>
<th></th>
<th>(4.3-1) bivariate correlation</th>
<th>(4.3-2) five year time dummies</th>
<th>(4.3-3) (4.3-1) with (4.3-2)</th>
<th>(4.3-4) (4.3-3) with controls for stage and location effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D INTENSIVE</td>
<td>0.769 (0.301)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARD INVESTED EARLY</td>
<td></td>
<td></td>
<td>0.790 (0.392)</td>
<td></td>
</tr>
<tr>
<td>MASS. LOCATED</td>
<td></td>
<td></td>
<td></td>
<td>0.857 (0.395)</td>
</tr>
<tr>
<td>“FAR” LOCATION</td>
<td>-0.206 (0.566)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARD INVESTED 1946-1950</td>
<td>0.707 (0.375)</td>
<td>0.496 (0.393)</td>
<td>0.238 (0.466)</td>
<td></td>
</tr>
<tr>
<td>ARD INVESTED 1951-1955</td>
<td>1.581 (0.627)</td>
<td>1.835 (0.681)</td>
<td>1.715 (0.735)</td>
<td></td>
</tr>
<tr>
<td>ARD INVESTED 1956-1960</td>
<td>1.307 (0.412)</td>
<td>1.248 (0.426)</td>
<td>1.178 (0.496)</td>
<td></td>
</tr>
<tr>
<td>ARD INVESTED 1961-1965</td>
<td>0.861 (0.427)</td>
<td>0.721 (0.435)</td>
<td>0.665 (0.451)</td>
<td></td>
</tr>
<tr>
<td>CONSTANT</td>
<td>-0.253 (0.254)</td>
<td>-0.431 (0.265)</td>
<td>-0.982 (0.354)</td>
<td>-0.981 (0.472)</td>
</tr>
<tr>
<td>LL</td>
<td>-57.310</td>
<td>-53.458</td>
<td>-50.046</td>
<td>-45.922</td>
</tr>
</tbody>
</table>

Dependent Variable = Pr (GAIN)

N = 91 observations
<table>
<thead>
<tr>
<th>Name</th>
<th>Title &amp; Institutional Affiliation</th>
<th>Interview Type</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inventors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fogarty, Thomas J.</td>
<td>Founder, Three Arch Venture Partners; President of Fogarty Engineering; Professor of Surgery, Stanford Medical Center; Winner, Lemelson/MIT Prize for Innovation, 2000.</td>
<td>In person, Portola Valley, CA</td>
<td>March 1999</td>
</tr>
<tr>
<td>Langer, Robert</td>
<td>Professor of Chemical &amp; Biomedical Engineering at MIT. Winner, Lemelson/MIT Prize for Innovation, 1998</td>
<td>In person, MIT</td>
<td>April 1999</td>
</tr>
<tr>
<td>Stevens, John</td>
<td>Co-Founder &amp; CTO, Heartport, Inc.; Professor of Cardiothoracic Surgery, Stanford University Medical Center</td>
<td>By telephone</td>
<td>May 1999</td>
</tr>
<tr>
<td><strong>Medical Device Executives</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chonette, David</td>
<td>Former President, Edwards Labs and American Hospital Supplies; Former Managing Partner, Brentwood Associates Venture Capital</td>
<td>By telephone</td>
<td>April 1999</td>
</tr>
<tr>
<td>Keston, Randy</td>
<td>Manager of R&amp;D, CardioGenesis</td>
<td>In person, Sunnyvale, CA</td>
<td>March 1999</td>
</tr>
<tr>
<td>Pax, Maggie</td>
<td>Business Manager, Hewlett Packard Medical Products</td>
<td>By telephone</td>
<td>Feb. 1999</td>
</tr>
<tr>
<td>Will, Allan</td>
<td>Former president, Devices for Vascular Intervention; Former president, AneuRx; Chairman, the Foundry</td>
<td>By telephone</td>
<td>April 1999</td>
</tr>
<tr>
<td>Williams, Raymond</td>
<td>Co-founder &amp; President, Advanced Cardiovascular Systems; member, Band of Angels</td>
<td>By telephone</td>
<td>April 1999</td>
</tr>
<tr>
<td><strong>Academics</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mark, Roger</td>
<td>Professor of Health Sciences and Technology, joint program at Harvard and MIT</td>
<td>In person, MIT</td>
<td>March 1999</td>
</tr>
<tr>
<td>Yeung, Alan</td>
<td>Professor of Interventional Cardiology, Stanford Medical Center</td>
<td>In person, Palo Alto, CA</td>
<td>March 1999</td>
</tr>
<tr>
<td><strong>Investors</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Douglass, David</td>
<td>General Partner, Delphi Ventures</td>
<td>By telephone</td>
<td>Feb. 1999</td>
</tr>
<tr>
<td>Jaffe, Ross</td>
<td>General Partner, Brentwood Associate Venture Capital</td>
<td>By telephone</td>
<td>April 1999</td>
</tr>
<tr>
<td>More, Robert</td>
<td>General Partner, Domain Associate Venture Capital</td>
<td>By telephone</td>
<td>March 1999</td>
</tr>
<tr>
<td>Ruvelson, Alan</td>
<td>Founder and President, First Midwest Investment Corporation</td>
<td>In person, Minneapolis, MN</td>
<td>July 1999</td>
</tr>
<tr>
<td><strong>Other Informants</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grossman, Jerome</td>
<td>Ex-President, New England Medical Center; CEO of Health Quality, Inc.</td>
<td>By telephone</td>
<td>March 1999</td>
</tr>
<tr>
<td>Hicks, Brian</td>
<td>Director of Corporate Research and Licensing, Brigham &amp; Women’s Hospital</td>
<td>In person, Boston, MA</td>
<td>Feb. 1999</td>
</tr>
<tr>
<td>Miller, Iain</td>
<td>Licensing Associate, Massachusetts General Hospital</td>
<td>In person, Boston, MA</td>
<td>March 1999</td>
</tr>
<tr>
<td>Reid, Proctor</td>
<td>Associate Director of Programs, National Academy of Engineering</td>
<td>By telephone</td>
<td>March 1999</td>
</tr>
<tr>
<td>Rhoes, David</td>
<td>Director, Bakken Library &amp; Museum (on medical devices)</td>
<td>In person, Minneapolis, MN</td>
<td>April 1999</td>
</tr>
</tbody>
</table>
Table 4.5
Selected Thomas J. Fogarty Startups

<table>
<thead>
<tr>
<th>Startup Name</th>
<th>Founding Date</th>
<th>Business Description</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventritex</td>
<td>March 1985</td>
<td>Implantable defibrillators</td>
<td>IPO 1/92 netting $59M at market cap of $298M; St. Jude subsequently acquired for $505M in stock; co-founded by Ray Williams</td>
</tr>
<tr>
<td>Cardiovascular Imaging</td>
<td>November 1986</td>
<td>Intraluminal ultrasound systems</td>
<td>IPO 4/92; netted $10M at market cap of $45M; Acquired by Boston Scientific 3/95 for $100M in stock</td>
</tr>
<tr>
<td>Systems</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Devices for Vascular</td>
<td>February 1989</td>
<td>Atherectomy devices</td>
<td>Acquired by Eli Lilly 3/89 for $50M and $150M earnout; co-founded by John Simpson</td>
</tr>
<tr>
<td>Intervention</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LocalMed</td>
<td>April 1992</td>
<td>Catheter-based drug delivery system</td>
<td>Private; co-founded by John Simpson</td>
</tr>
<tr>
<td>General Surgical Innovations</td>
<td>April 1992</td>
<td>Balloon dissector for creating surgical workspace to enable less invasive surgical procedures</td>
<td>IPO 5/96; netted $41M at market cap of $190M</td>
</tr>
<tr>
<td>AneuRx</td>
<td>January 1993</td>
<td>Abdominal stent grafts</td>
<td>Acquired by Medtronic 4/96</td>
</tr>
<tr>
<td>Biopsys Medical</td>
<td>July 1993</td>
<td>Less invasive breast biopsy system</td>
<td>IPO 4/96; netted $35M at market cap of $146M</td>
</tr>
<tr>
<td>Cardio-Thoracic Systems</td>
<td>November 1993</td>
<td>Minimally invasive coronary artery bypass instruments</td>
<td>IPO 3/96; netted $74M at market cap of $221M</td>
</tr>
</tbody>
</table>

Source: Longman (1996); Venture Economics Database.
References


Arora, A., A. Fosfuri, and A. Gambardella (1999). "Markets for Technology (Why do we see them, why don't we see more of them, and why should we care)," Universidad Carlos III, *Working Paper* No. 99-17(4).


