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ESSAYS ON THE VALUATION AND SYNDICATION OF VENTURE CAPITAL INVESTMENTS

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ABSTRACT

This dissertation aims at contributing to the body of literature covering the field of entrepreneurial finance. More specifically, the study focuses on the valuation and syndication of venture capital investments. The dissertation comprises a theory review and four essays, each of which makes distinct but complementary contributions to both theory and practice.

The first essay of this dissertation constructs and tests a binomial pricing model for staged venture capital investments. Using the valuation data of 421 U.S. venture capital transactions and 176 initial public offerings, the essay finds that the pricing model is consistent with previous knowledge on the risk-return profile of venture capital investments. The results further confirm the hypothesis that early-stage ventures have higher implied risk and implied volatility of returns than more established ones. The results of the essay imply that pricing models that assume constant volatility, unlike the binomial model, are not likely to be applicable in venture capital or similar project valuation settings.

The second essay demonstrates how investor prominence affects the valuations of venture capital backed companies. Employing a thorough data set of over 32,000 U.S. venture capital investments between 1990 and 2000, the essay shows that certification ability gives prominent venture capitalists bargaining power that they utilise when investing in ventures for the first time. In line with the asymmetric information and signalling theories, it is found that the reputation of existing venture capital investors adds value in future financing rounds. The results are robust to potential selection biases, alternative measures of investor prominence, the existence of additional value adding mechanisms, and different sampling periods.

The third essay examines the relationship between investment syndication and the efficiency of venture capital firms. Arguments derived from the theoretical motives for syndication predict that syndication relationships allow venture capitalists to be more efficient in completing investments and in making their portfolio companies public. Utilising an extensive data set on the venture capital investments of the 100 largest U.S. venture capital firms between 1986 and 2000, the essay demonstrates that syndication has an impact on venture capitalists' efficiency in both of these areas. The frequency of syndicating investments accelerates the process of investing in new portfolio companies, whereas the diversity of the syndication relationships improves the venture capitalists' ability to create public companies from their portfolio companies. Furthermore, the essay demonstrates that uncertainty moderates the impact of syndication on firm efficiency. Firms with uncertain venture portfolios benefit more from syndication relationships.

The fourth essay compares resource-based and social structural explanations for the network positions and the performance of venture capital firms. A distributed lag analysis of an extensive data set of the 100 largest U.S. venture capital firms and their syndicate structures between 1986 and 2000 suggests that venture capital firms in central network positions increase their market share of portfolio company initial public offerings in subsequent years. Consistent with the social structural argument, the results further demonstrate that prior network positions tend to determine future positions. An analysis of causality reveals that past network position tends to dominate the observable quality of firm resources as a determinant of the subsequent performance and position of the firm. The results further imply that the structure of venture capital syndication networks is rigid and involves high barriers to entry, and that the acquisition of general partners contributes to changes in existing network positions.

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Tuukka Seppä

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1 INTRODUCTION

1.1 Background

During the last decade, venture capital investing grew enormously. According to the records of Venture Economics, a U.S. research firm, venture capital disbursements grew 25-fold between 1990 and 2000. The growth was rapid both in the North America, the origins of venture capital, and in Europe and Asia. Despite the radical downturn in venture capital investment activity after the high-technology stock market collapse in 2000 and 2001, the macroeconomic role of venture capital is still the same as when the formal venture financing industry began to establish in the United States soon after World War II. Venture capital firms exist in order to provide financing for new, high-risk, and growing companies, thereby fuelling economic growth and renewal. Companies that have received venture capital funding have created nearly one third of the total market value of all public companies in the United States (Gompers and Lerner, 2001: 12). The venture capital industry has also served as an accelerator of innovative output. Venture funding accounted for as much as 14% of all U.S. innovative activity in 1998 (Kortum and Lerner, 2000).

Previous academic research on venture capital has covered several areas. Researchers have extensively analysed and documented the venture capital investment process (Tyebjee and Bruno, 1984; MacMillan *et al.*, 1985; 1987; Sahlman, 1990; Gompers, 1995), venture capital contracting, agency problems, and incentives (Admati and Pfleiderer, 1994; Sapienza and Gupta, 1994; Sapienza and Korsgaard, 1996; Kirilenko, 2001), the value added of venture capital investors (Sapienza, 1992; Hellman and Puri, 2000; 2002), and venture capital initial public offerings (Barry *et al.*, 1990; Gompers and Lerner, 1998; Brav and Gompers, 1997; Stuart *et al.*, 1999).

Despite a wide variety of previous research on venture capital investing, several areas provide possibilities to expand the current body of knowledge significantly. Firstly, the valuation, risk, and return of venture capital investments have lacked rigorous empirical and theoretical research until recent years, partly due to the lack of access to data on the realised valuations of investments. Previous research has examined the risk and return of venture capital investments on an aggregate level of the fund or the firm (Huntsman and Hoban, 1980; Ruhnka and Young, 1991), or from a macroeconomic perspective using individual venture capital investments as the unit of analysis (Gompers and Lerner, 2000; Cochrane, 2001). Gompers and Lerner (2000) tested how money inflows into venture capital funds affect the valuations these funds pay for their investments. Cochrane (2001) examined selection bias in the analysis of venture capital valuations and rates of return. However, previous research has lacked attempts to model the value and the risk-return structure of venture capital investments. Similarly, empirical evidence on venture capital valuations is still scarce.

Secondly, the impact of the investor on the new venture has attracted a stream of research on the value added of venture capitalists (e.g., Hellmann and Puri, 2002). A handful of studies has also analysed the ability of venture capitalists to resolve informational asymmetries in the going public process (Barry *et al*., 1990; Megginson and Weiss, 1991; Gompers, 1996). However, previous knowledge on the impact of the investor on venture capital valuations prior to the exit is thin. Especially, researchers have not yet addressed whether the prominence and reputation of venture capital investors affect company valuations.

Thirdly, research on the syndication of venture capital investments has focused on the motives of syndication (Lerner, 1994b; Brander *et al*., 1999; Lockett and Wright, 2001; Anand and Piskorski, 2001) and the structure of venture capital syndication networks (Bygrave, 1988; Sorenson and Stuart, 2001). Syndication networks represent a key vehicle for venture capitalists to exchange information and resources (Bygrave, 1988), and to establish social status (Podolny, 2001). However, previous research has addressed neither the performance implications of network position nor the performance implications of different syndication strategies.

This dissertation contributes to these three areas of research on venture capital. By building hypotheses on the basis of received theories, the dissertation presents four essays on the valuation and syndication of venture capital investments. The essays contain novel empirical and theoretical results that expand the current body of knowledge on venture capital and related topics. Besides contributing to theory, the findings have important practical implications to venture capitalists seeking to maximise their performance, entrepreneurs seeking the optimal solution for financing their venture, and public policy makers.

1.2 Research problem and objectives

This dissertation focuses on examining the following research problem: *What is the impact of the prominence of venture capital investors on the valuations of new ventures, and what implications does the choice of investment syndication strategy have on investor prominence?* This overall research problem can be divided into four individual sub-problems.

Firstly, I analyse *how well a binomial option-based pricing framework performs in the analysis of the valuations and the risk-return structure of venture capital investments*. While the valuation of new ventures is a process that involves significant uncertainties, research in real options has shown that venture capital investments are conceptually decomposable into a series of options. The theory also suggests that the valuation of venture capital investments could be enhanced with appropriate models. Empirical testing of option-based pricing frameworks adds to the understanding of the feasibility of such models, and expands the current body of knowledge on the risk-return structure of venture capital investments.

Secondly, I examine *the impact of the prominence of venture capital firms on the valuations of entrepreneurial ventures*. Outside investors confront informational asymmetries when investing in new ventures, but the presence of prominent venture capitalists inside the venture may reduce the impact of these asymmetries. Similarly, prominent venture capitalists may be able to bargain lower valuations for their own investments into new ventures because their presence might reduce informational asymmetries and thus add value in future financing rounds that involve new outside investors.

Thirdly, I examine *whether the choice of syndication strategy affects the efficiency of venture capital firms*. Venture capitalists can adjust their syndication strategies across a spectrum of two variables, the frequency of syndication and the diversity of syndication relationships. Potentially, both the frequency and the diversity of syndication have an impact on the efficiency of the venture capital firm in completing deals and in converting the portfolio companies into successful exits. Efficiency has a direct impact on the performance of the firm and thus, according to the definition used in this dissertation, reinforces the prominence of the focal venture capital firm.

Finally, I analyse *whether positions in the syndication network of venture capital firms are major determinants of the subsequent performance of these firms, and whether past positions or the observable quality of resources determine subsequent positions*. By syndicating investments with one another, venture capital firms acquire positions in a collaboration network. Firms that are central in the network and thus serve as exchange partners to several other firms have high status, gain informational benefits and have an enhanced access to the resources of the exchange partners. On the contrary, peripheral firms have low status and inferior access to information and partners' resources. Thus, a central position may improve firm performance. However, previous research provides competing explanations on the dominant determinant of positions. On one hand, the resource-based view of the firm stresses that the quality of the firm's resources determines its position. On the other hand, the social structural view argues that prior positions and exchange relationships are the primary determinants of position.

1.3 Research approach and methods

Throughout the dissertation, I focus on testing hypotheses derived from received theories using quantitative empirical methods. In contrast to the other essays, the first essay is partly constructive, as a valuation framework is derived and empirically tested. The other essays concentrate solely on building theory-based hypotheses and testing them empirically. The research approach requires an extensive review of previous theoretical and empirical research in several areas, and excludes potentially interesting explorative findings, but also enables drawing robust conclusions from the results. By building on previous theoretical and empirical research, by developing novel yet empirically testable hypotheses on the research questions, by running rigorous empirical

tests on the hypotheses, and by drawing theoretically and practically relevant conclusions from the results, this dissertation aims at contributing to the body of knowledge on venture capital and several related areas of theoretical research.

The core venture capital investment data sets collected from the Venture Economics Disbursements database are supplemented in each essay using data from several other sources, including Venture Economics Fund commitments database, Venture Economics Firms database, Securities Data Corporation's New Issues database, U.S. Securities and Exchange Commission's Initial Public Offering prospectuses (EDGAR database), past issues of Pratt's Guides to Venture Capital Sources, the résumés of individual venture capital firm general partners, and U.S. Federal Reserve Bank of Chicago interest rate databases. The hypotheses are tested using quantitative statistical methods. These methods include ordinary least squares (OLS) regression (essay 1), heteroskedasticity-consistent full maximum likelihood Heckman sample selection regression (essay 2), time series – cross sectional maximum likelihood generalised least squares (GLS) regression with fixed effects (essay 3), and time series – cross sectional maximum likelihood GLS regression with distributed lags and fixed effects (essay 4).

1.4 Scope and limitations

This dissertation focuses on the valuation and syndication of venture capital investments. The scope is limited to independently managed risk capital that focuses on equity or equity-linked investments in privately held, high-growth companies, sometimes referred to as standard venture capital investments (Gompers and Lerner, 1999b). The scope excludes buyouts, consolidations, mezzanine and distressed debt investments, and other forms of private equity.

The empirical data of this dissertation is geographically limited to the United States. The reason to focus on the U.S. venture capital industry is that the USA is practically the only part of the world with a long enough history of established venture capital activity to enable the analysis of the research questions. A large amount of empirical data is required in order to answer the key questions raised in this dissertation, and some of the questions also require longitudinal data sets. Another reason to focus on the U.S. is that focusing on a single country reduces unobserved country-specific heterogeneity in the sample, and allows drawing more robust – albeit less general – conclusions from the empirical results.

The main limitation of this dissertation is the source of venture capital investment data. Most of the data related to venture investments comes from the Venture Economics database. While this database is the official source of investment data of the U.S. National Venture Capital Association, and the data have been extensively used in previous research published in the top-tier journals (e.g., Lerner, 1994a; Lerner, 1995; Gompers, 1995; Gompers, 1996), relying too much on one source might cause observer bias and lead to wrong interpretations of the results. Although all the essays of this

dissertation supplement the Venture Economics data in several ways using independent sources, the core entries related to individual venture capital investments or financing rounds are always from Venture Economics records. However, previous research has identified in detail the relatively minor deficiencies of the Venture Economics database (Gompers and Lerner, 1999b), and this dissertation attempts to take into account these and other problematic issues observed during the research process as fully as possible. As a result, I do not expect the choice of data sources to introduce any systematic biases to the results.

1.5 Definitions

Several terms in this dissertation require rigorous definitions. Firstly, the topic of this dissertation is *venture capital*. The U.S. National Venture Capital Association defines venture capital as "money provided by professionals who invest alongside management in young, rapidly growing companies that have the potential to develop into significant economic contributors" (NVCA, 2002). In a similar manner, Wright and Robbie (1998) define venture capital as investment by professional investors of long-term, unquoted, risk equity finance in new firms where the primary reward is capital gain supplemented by dividend yield. Gompers and Lerner (1999b: 11) define venture capital as "independently managed, dedicated pools of capital that focus on equity or equity-linked investments in privately held, high-growth companies".

Especially in the United States, a distinction is often made between "venture capital" and "private equity". Whereas venture capital refers to the investment activities of professional funds that purchase equity or equity-linked stakes in new, unquoted firms, private equity includes funds devoted to venture capital, leveraged buyouts, consolidations, mezzanine and distressed debt investments, and a variety of hybrids such as venture leasing and venture factoring (Gompers and Lerner, 1999b). Non-venture-capital private equity investments are often associated with companies that have already reached later stages of development and may even be quoted on a stock exchange. These investments are most often related to the restructuring of existing companies.

Venture capital is, however, much more than a certain subset of the financial markets. Gompers and Lerner (1999b) refer to venture capital as a cyclical process that starts from fundraising and proceeds to investing the funds into promising companies, monitoring them, adding value to them, returning capital to the limited partners, and restarts with the raising of new, follow-on funds. Viewing venture capital as a cycle stresses the empirical fact that venture capital is a continuous process in which the ability to raise follow-on funds and continue business largely depends on the success of the previous funds (Gompers and Lerner, 1999b).

Active involvement in the development of the portfolio companies also characterises venture capital. Venture capitalists aim at adding value to their portfolio companies through various activities, including monitoring financial and operational performance,

recruitment of management, arranging financing from complementary sources, serving as a sounding board to the entrepreneur team, arranging incentive plans, providing access to auditors, lawyers, and investment banks, and setting company policies (Gorman and Sahlman, 1989; Sapienza, 1992; Hellman and Puri, 2000; 2002).

Another important factor that separates venture capital from other similar types of financial institutions or sources of risk capital is the organisation of the investment activities (Sahlman, 1990). Venture capital is typically organised in limited partnerships holding funds that are professionally managed by general partners. The capital is raised from limited partners that are most often institutional investors such as pension funds. The general partners are compensated with 20-25% of the funds' returns, and a 1.5-3% fixed fee on capital under management (Gompers and Lerner, 1999a), while the limited partners get the rest. The funds have a limited lifetime, usually 10 years, although extensions are frequently granted (Sahlman, 1990). When investments are liquidated, funds are returned to the limited partners either in the form of portfolio company shares or cash (Gompers and Lerner, 1998).

Valuation refers to two distinct issues in this dissertation. Firstly, valuation means the process of placing a monetary value on an investment opportunity. This definition does not restrict the concept to cover only certain procedures of quantitative analysis; rather, valuation is the process of determining the subjective monetary value of an investment opportunity. This definition of valuation applies in this dissertation in the context of valuation models and processes. The second meaning for valuation is the joint result of the valuation process and buyer-seller negotiations. In this context, valuation refers to the price of an investment, a security, or a company that the buyer and seller agree upon prior to completing a transaction.

Syndication. Wilson (1968) defined a syndicate as "a group of individuals who must make a common decision under uncertainty that will result in a payoff to be shared jointly among them". In the context of financial markets, syndicates are groups of investors that jointly make an investment decision. These syndicates are commonly formed among lenders (syndicated loans) and equity investors, venture capitalists in particular. In the context of venture capital, Bygrave (1987; 1988) and Lerner (1994b) recognised a syndication relationship when at least two venture capitalists invested in the same venture in the same financing round. In this dissertation, syndication refers to organised co-investment by at least two venture capital firms in the same venture at the same time.

Prominence. According to the Webster and Oxford Current English dictionaries, the word "prominent" means something that stands out, is widely and popularly known, or leading within a comparable group. A direct synonym for prominence is "eminence". Eminent is something "standing out so as to be readily perceived or noted" or "standing above others in some quality". "Prominent" is also close to "prestigious", a word referring to something that has standing or estimation in the eyes of people, or a

commanding position in people's minds. Being prestigious is also closely related to having "high status"; however, status is clearly a more social concept than prominence. Status means "the rank in relation to others … in a social order, community, class, or profession" or "the relative rank in a hierarchy of prestige". While prominence is something outstanding determined according to observable external characteristics, status and prestige are the outcomes of a social recognition process. Status and prestige are less directly related to observable external characteristics and more dependent on the evaluator in question. In this dissertation, prominence refers to the quality of an economic actor measured using the observable external characteristics of the actor, such as past performance or experience.

1.6 Structure of the dissertation

The remainder of this dissertation is organised as follows. Chapter two of this introductory section provides an overview of relevant research on the venture capital topic and related theories. Chapter three is a summary of the four essays of this dissertation. The first essay is called "Valuation of Venture Capital Investments: Empirical Evidence". It is followed by the second essay "Certification of Venture Capital Investments: The Impact of Investor Prominence on Company Valuations", the third essay "Syndication and the Efficiency of Venture Capital Firms", and the fourth essay "How the Rich Become Richer in Venture Capital: Firm Performance and Position in Syndication Networks".

2 AN OVERVIEW OF RELEVANT RESEARCH

2.1 Venture capital

2.1.1 Brief history

As discussed in the previous section, venture capital refers to money invested by professional investors in young, rapidly growing companies that have the potential to develop into significant economic contributors. The activity of financing entrepreneurs has naturally existed almost as long as entrepreneurs themselves. Entrepreneurs have long had ideas that require more capital to implement than have entrepreneurs themselves. While debt financing could solve the lack of capital, new, high-growth, high-risk ventures that expect several years of negative earnings have typically been forced to seek alternative sources of money. At the time of Hammurabi, the Babylonian partnerships attempted to solve these issues (Gompers and Lerner, 1999b).

Venture capital represents one established solution to financing high-risk, high-reward ventures. The roots of the formal venture industry are in the United States and date back to the post-war 1940s. MIT, Harvard Business School, and local business leaders set up the first modern venture capital firm, American Research and Development (ARD) in 1946 to commercialise the technologies developed for World War II. While the success of ARD's investments was very variable, its investment in Digital Equipment Corporation in 1957 grew from $70,000 to $355 million, and generated almost half of ARD's lifetime profits (Gompers and Lerner, 1999b). The first venture capital limited partnerships were formed in the late 1950s led by Draper, Gaither, and Anderson. However, Gompers and Lerner (1999b) report that funds governed by limited partnerships exceeded 50% of the total venture pool only as recently as 1982. Thereafter, independent limited partnerships have governed approximately 80% of total U.S. venture capital funds.

Money inflows into venture capital and disbursements into portfolio companies have experienced two periods of fast growth (Figure 1). The first growth period followed the 1979 amendment of the U.S. "prudent man" rule governing pension fund investments (Gompers and Lerner, 1999b). The change allowed pension funds to invest in high-risk assets, including venture capital, and led to a significant expansion of the venture capital pool. The $0.56 billion of fundraising in 1979 quickly grew to $4.2 billion in 1983.

However, the explosion of the venture capital market in the late 1990s totally outweighs the first growth period of the industry. The years 1998 to 2000 saw a tremendous expansion of the Internet and related industries following Netscape's IPO in August 1995. Fundraising shot up from $18 billion in 1997 to $110 billion in 2000, and disbursements followed the same growth pattern. New venture capital partnerships were

formed at a pace never seen before. Investments were made in new ventures at an outrageous frequency, and IPO exits could be realised in less than two years of the first seed investment at extremely attractive valuations.

The favourable IPO market that lasted until the March 2000 collapse of the Nasdaq and Internet shares was most likely a major contributor to the seemingly unlimited expansion of the venture capital industry. An attractive exit market formed the basis for "getting rich quickly", and obviously raised expectations about potential exit valuations for new venture capital investments. However, the long downward slide of the public equity market after early 2000 caused a drastic drop in venture capital activities. In 2001 and early 2002, the IPO window was no longer open, and a growing number of Internet-related bankruptcies raised investors' doubts about the sustainability of the current level of venture capital activity. Investments soon slowed down significantly. U.S. venture capital fundraising and disbursements quickly tumbled by 60% to 70% of the 2000 peak. 2001 saw only $47 billion in venture capital disbursements and $40 million in fundraising, and in early 2002 the industry slowed down even more. The late 1990s clearly represented a period when a great deal of money was chasing too few high-quality deals – following a similar but significantly magnified pattern as that documented by Gompers and Lerner (2000) in their study of the impact of fund inflows on venture capital valuations before 1996.

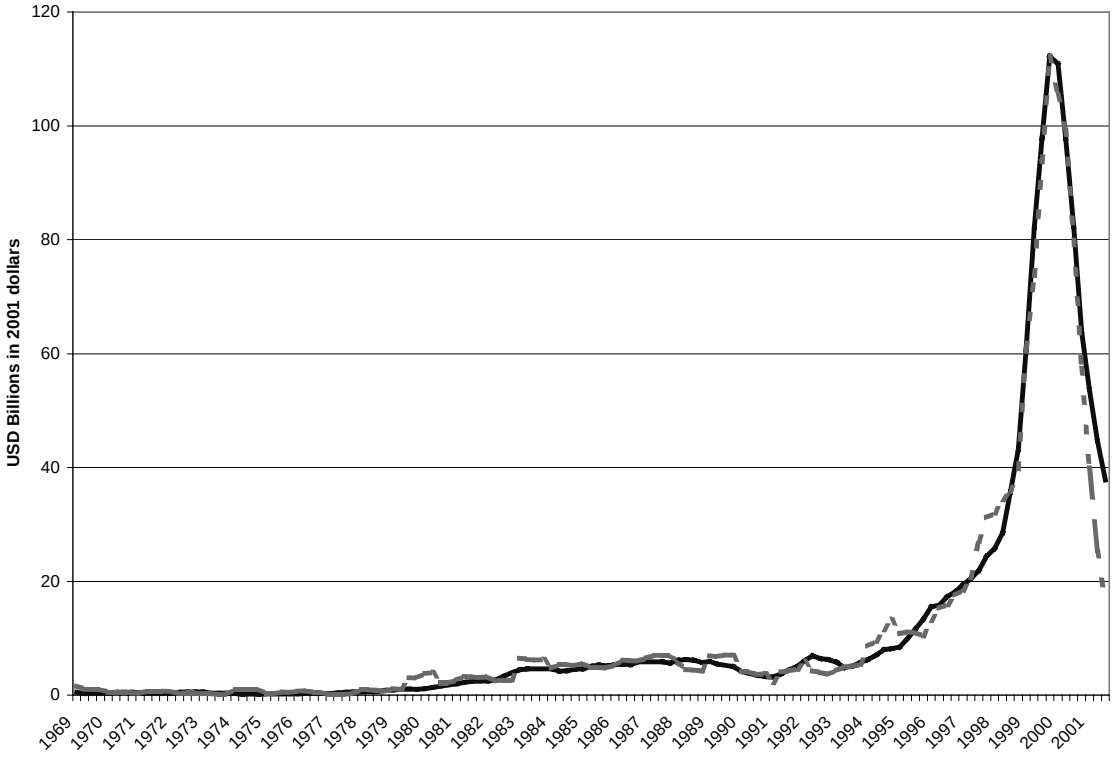

Figure 1 *Rolling 12-month level of fundraising (dashed line) and disbursements (solid line) by U.S. venture capital investors in 2001 dollars between January, 1969 and June, 2002. Compiled from Venture Economics databases in October, 2002.*

2.1.2 Key areas of previous research

In this section, I go through most of the venture capital research published in refereed journals, including some of the key books on the topic. More weight is given to the areas most relevant to this dissertation. These areas include investment valuation, the certification role of investors, and the syndication of investments.

Literature reviews. Venture capital is a multifaceted topic, and it is not possible to consider all aspects of previous research in this short review. I point out here some review articles and books that can provide a more comprehensive view of the area.

Timmons and Bygrave (1986) can perhaps be regarded as the first authors to publish an overview of venture capital investing and research. While Tyebjee and Bruno (1984) modelled the venture capital investment process, Timmons and Bygrave (1986) provided the first holistic overview of the professional entrepreneurial financing industry. Following that, Sahlman (1990) published a widely cited paper on the structure and governance of U.S. venture capital organisations. His work documented the organisation of venture capital investing, the deal-making process, deal structuring, and other characteristics typical of venture capital financial institutions. Soon after the temporary fall in venture capital activity in the early 1990s, Bygrave and Timmons (1992) published a popular book *Venture Capital at the Crossroads*, summarising the key characteristics of venture capital investing and recent developments in the marketplace. In their review papers, Barry (1994) and Wright and Robbie (1998) summarised a large portion of the venture capital research conducted before their efforts.

One of the most comprehensive review books on venture capital research was published by Gompers and Lerner (1999b). Although the book summarises mostly the authors' own research, it covers almost all phases of the venture capital cycle from fundraising to returning the funds to the limited partners. The book was supplemented in 2001 with a more practitioner-oriented volume (Gompers and Lerner, 2001). Many of the key pieces of venture capital research that are cited in current papers, including this dissertation, have appeared in the "financial economics" stream of venture capital research led by the Harvard professors, Gompers and Lerner.

Valuation, risk, and return. Previous research reports attractive returns for venture capital investments. Huntsman and Hoban (1980) made one of the first structured attempts to analyse the risk-return trade-off of venture capital investments. They found that venture capital investments offer attractive returns, on average 18.9% year-on-year, but that the rate of return on the investment portfolio is highly sensitive to the number of successful investments it contains. Small venture capital portfolios also tended to have a significant probability of yielding rates of return below zero, suggesting that the

minimal capital requirement for a venture capital fund is relatively large, at least several millions of U.S. dollars in 1980.

Ruhnka and Young (1991) developed a framework for venture capitalist risk perceptions and risk-reduction strategies. Additionally, they provided empirical evidence regarding the stage-wise risk of venture capital investments. While venture capitalists require an average rate of return of 65-70% for seed-stage investments, exit stage investments can be accepted at 25-35% return. Thus, early-stage investments are regarded as significantly more risky than later-stage investments. Furthermore, venture capitalists require compensation for their efforts in developing the venture. Manigart *et al*. (2002) surveyed the determinants of venture capitalists' required rates of return in five countries. They found that VCs with more intensity of involvement require higher rates of return, and that the rate of return declines with the stage of development of the venture.

The analysis of venture capital valuations is not as straightforward as the analysis of public market valuations or share prices. Because of the fluctuations in the supply and demand of venture capital, investment valuations are not always determined according to the rules of efficient markets. Gompers and Lerner (2000) examined how the inflow of capital into venture funds affects the valuations of these funds' new investments. Their results indicate that fund inflows tend to inflate venture valuations, because excess money available for investments intensifies competition for a limited number of attractive targets. Furthermore, Gompers and Lerner (2000) did not find changes in valuations to be related to the ultimate success of the ventures. Contrary to the efficient market hypothesis, changes in the supply of capital were found to have an immediate impact on the valuations venture capitalists place on new investments.

Furthermore, analysing venture capital valuations and the true return on investments is difficult because typical data sets available to researchers suffer from selection bias (Cochrane, 2001). Returns calculated from observed venture capital valuations and exits are biased because ventures that fail or remain private do not produce valuation observations. The return to IPO is an upward biased measure of the ex ante returns to potential venture capital investors. Cochrane (2001) found that a selection bias correction significantly attenuates the overly high average arithmetic returns observed for these investments.

Distribution of control and the structuring of shareholder agreements should also have a direct impact on venture capital valuations. Kirilenko (2001) presented a model of a relationship between a venture capitalist and an entrepreneur engaged in the formation of a new firm. Through theoretical modelling, he showed that the venture capitalist demands disproportionately higher control rights than his equity investment, and that the entrepreneur is compensated for the loss of control through improved valuations.

Investor certification. The potential certification ability of venture capitalists was recognised in the financial economics stream of research after the role of underwriters in the equity issuing process had been intensively examined by Leland and Pyle (1977),

Campbell and Kracaw (1980), and Booth and Smith (1986), among others. Megginson and Weiss (1991) performed one of the first thorough tests of the ability of venture capitalists to certify the prices of initial public offerings. The presence of venture capitalists in issuing firms results in significantly lower initial returns and gross spreads, and therefore serves to maximise the net proceeds to the firm. Megginson and Weiss (1991) listed three tests that must be met for third-party certification to be reliable to outside investors. Firstly, the certifying agent must have reputational capital at stake that would be forfeited by giving a false certification. Secondly, the value of the agent's reputational capital must be larger than the largest possible one-time wealth transfer or side payment that could be obtained by false certification. Thirdly, it must be costly for the issuing firm to purchase the services of the certifying agent, and this cost must be an increasing function of the scope and potential importance of the information asymmetry regarding intrinsic firm value.

Further research supports the price-certifying role of venture capitalists. In the light of Canadian empirical data, Amit *et al*. (1998) concluded that venture capitalists exist because the market for entrepreneurial finance is characterised by informational asymmetries and moral hazard. Because venture capitalists can reduce these market failures, they have an advantage over other investors in providing funds for new ventures. Nevertheless, venture capitalists tend to prefer projects where informational asymmetries are less severe.

Venture capitalists recognise that an ability to certify is valuable, and therefore attempt to gain reputation on the market. Gompers (1996) found that new venture capitalists seek to establish a reputation by making portfolio companies public earlier than more established venture capitalists in order to raise capital for new funds. Young venture capitalists are also associated with issues related to less credible certification. They serve a shorter time on the board prior to IPO and hold smaller equity stakes in ventures.

Financial markets recognise that venture capitalists can certify the quality of recently listed companies. Gompers and Lerner (1998) examined how venture capitalists distribute shares to the limited partners after a portfolio company IPO, and how the distribution affects the value of the portfolio company. Their evidence suggested that the market reacts to distributions as it reacts to insider trading; the abnormal return of the ventures around the distribution dates is significantly negative. Thus, the loss of venture capitalist certification acts as a negative signal to the market.

Syndication. Research on the syndication of venture capital investments was initiated by Bygrave (1987; 1988). Using a resource exchange model, Bygrave (1987) reasoned that the relative amount of syndication is explained primarily by the degree of uncertainty associated with an investment rather than by the sum of money invested. Additionally, sharing information appeared to be a more significant reason for syndication than spreading financial risk. As a result, venture capitalists should gain access to the network of other investors by having knowledge that other firms need (Bygrave, 1987). Bygrave

(1988) further examined the structure of venture capital syndication networks. While U.S. venture capitalists appeared to be loosely connected as an overall group, venture capitalists focusing on companies in a highly innovative industry, and companies in certain geographical areas, appeared very tightly coupled. Bygrave (1988) pointed out that the network of high-technology VCs disseminates deal-related information relatively quickly.

In addition to the sharing of information, five other rationales have been proposed to explain why venture capital firms syndicate. Venture capitalists may syndicate to share financial value at risk (Lockett and Wright, 2001), to improve decision-making by joint decisions (Lerner, 1994b), to window dress (Lerner, 1994b), to improve capabilities to add value (Brander *et al*., 1999), and to establish social status (Podolny, 2001). Experienced venture capitalists typically syndicate first-round investments with investors having a similar level of experience (Lerner, 1994b). Because experienced venture capitalists tend to be selective in their choice of first-round syndication partners, access to the opinions of other investors is a motivation for syndication. In later rounds, less experienced venture capitalists are invited to join the syndicates. In contrast, when established firms join as new investors in later rounds, the valuation has often increased sharply before the investment. This provides support for the window dressing hypothesis. However, equity stakes show relatively little variation between financing rounds, suggesting that syndication seeks to maintain ownership shares constant in order to avoid exploiting informational advantages (Admati and Pfleiderer, 1994; Lerner, 1994b).

The improvement of the capacity to add value to the portfolio companies may also motivate syndication. Brander *et al*. (1999) compared the value-added hypothesis, the selection hypothesis, and the financial risk-sharing hypothesis as explanations for syndication, and did not find evidence to support financial risk-sharing as a major rationale for syndication. Instead, their results favoured the value-added hypothesis. Similarly, Lockett and Wright (2001) compared competing finance, resource-based, and deal flow explanations for the syndication of venture capital investments. The motives of syndicating a deal appeared to be driven more by financial considerations than the exchange of firm-specific resources or deal flow. However, the resource exchange argument, i.e., value added, was far more important for venture capitalists focusing on early-stage investments rather than buyouts.

The social structure of syndication networks affects both the flow of information and the propensity to syndicate investments. Sorenson and Stuart (2001) examined syndication and the spatial distribution of U.S. venture capital investments. While venture capitalists in general are geographically and industry-wise extremely focused, syndication networks diffuse information across these boundaries, and expand the spatial radius of exchange. Venture capitalists that build axial positions in the syndication network invest more frequently in spatially distant companies. Position in the syndication network also affects the possibilities venture capitalists have for establishing new syndication relationships.

Anand and Piskorski (2001) found that firms in central positions in the syndication network can establish co-operation relationships with other firms regardless of their financial resources. Conversely, peripheral firms can establish ties only if they possess financial resources. Thus, central venture capitalists tend to sustain their positions over time.

Performance of VC firms. Relatively few studies have examined the performance of venture capital firms. One approach is to look at the returns of venture capital funds on the money invested (Brophy and Gunter, 1988; Bygrave, 1989; Chiampou and Kallet, 1989). This stream has to some extent suffered from a lack of data on the actual internal rates of returns of venture capital funds. However, all three studies have been able to gather a representative dataset of U.S. or multiple-country VCs by conducting surveys or by examining a selected sample of venture capital firms. Generally, the results state that venture capital funds provide returns in excess of 15% per annum, but that the standard deviation of the returns is very high compared to public market securities. Another approach would be to look at the returns on the individual investments that ultimately constitute the performance of a venture capital firm. However, selection bias and the limited amount of data available for non-public companies has severely limited the adoption of this approach (Cochrane, 2001).

Relationship between venture capitalists and limited partners. This stream includes research on the organisation of venture capital activities and fundraising, contracting between investors and venture funds, incentives of venture capitalists to act in the interest of the limited partners, and the compensation of the venture capital firm's general partners. Among others, Sahlman (1990), Gompers and Lerner (1996), Black and Gilson (1998), Gompers and Lerner (1999a), and Gifford (1997) have examined the topic.

The venture capital **investment process and selection criteria**, first modelled by Tyebjee and Bruno (1984), have been exhaustively examined using the survey method (MacMillan *et al.*, 1985; MacMillan *et al.*, 1987; Rea, 1989, Rah *et al.*, 1994), and the real-time policy capturing methodology (Zacharakis and Meyer, 2000). Similarly, related information acquisition strategies have been compared to those of bankers (Rosman and O'Neill, 1993). In contrast to typical bankers, venture capitalists typically focus on strategic data rather than historical financial data or projections when making investments (Rosman and O'Neill, 1993). Gompers (1995) analysed the optimal staging of venture capital investments, and noted that staging investments creates value to both the entrepreneur and the venture capitalist. In addition, several other authors have examined the investment process (Table 1).

Governance and contracting. The structuring of contracts between venture capitalists and entrepreneurs has been a popular topic of venture capital research. The agency perspective on contracting (Jensen and Meckling, 1976) is particularly popular in the finance-oriented papers (Sahlman, 1990; Sahlman, 1993; Admati and Pfleiderer, 1994;

Bergemann and Hege, 1998; Hellmann, 1998) as well as some papers in the management stream (e.g. Sapienza and Gupta, 1994; Fiet, 1995). The agency perspective typically assumes that the entrepreneur is an agent for the venture capitalist, who acts as the principal, providing funds at the entrepreneur's disposal. Conflicts in the parties' interests create ex ante agency costs that can be offset by properly structuring the investment contracts. For example, the gap between the entrepreneur's and the venture capitalist's future cash flow expectations can be closed by issuing call options to the entrepreneur (Sahlman, 1990). Managing the agency issues also requires venture capitalists to establish appropriate control mechanisms to oversee the portfolio companies (Lerner, 1995), and, strictly speaking, requires VCs to hold their equity stake constant across financing rounds (Admati and Pfleiderer, 1994).

Investor value-added. Do venture capitalists add value other than money, and do they have a different role from traditional financial intermediaries? Rosenstein (1988) explored the board work of venture capital backed new ventures, and found that boards consist of outsiders rather than insiders, that some outside members had a high degree of expertise, and that board meetings frequently revised strategic issues. Venture capitalists can also add value through learning effects. Barney *et al*. (1996) found that experienced entrepreneurs value both managerial and operational advice less than inexperienced entrepreneurs, but that current firm performance is not related to the evaluation of VC advice. Sapienza (1992) surveyed U.S. entrepreneurs on the role of venture capitalists, and noted that innovation intensity, frequency of contacts, open communication, and a conflict-free relationship between the VC and the entrepreneur enhance the impact of venture capital on company performance. MacMillan *et al*. (1988), Gorman and Sahlman (1989), Rosenstein *et al*. (1993), and Sapienza *et al*. (1996) further examined the mechanisms through which venture capitalists add value in their portfolio companies. Venture capitalists assist new ventures in monitoring financial and operational performance, recruitment of management, arranging financing from complementary sources, serving as a sounding board for the entrepreneur team, arranging incentive plans, providing access to auditors, lawyers, and investment banks, and setting company policies.

Evidence also suggests that venture capitalists play roles over and beyond those of traditional financial intermediaries. Gompers and Lerner (1999c) compared a large sample of corporate venture capital transactions to ordinary venture capital transactions. The data supported the existence of complementarities that allow corporations to add value to portfolio firms. Maula (2001) and Maula and Murray (2001) concluded that venture capitalists have complementary value-adding roles with other types of investors, such as corporate venture capitalists. Hellman and Puri (2000) found that venture capital financing is associated with a significant reduction in the time to bring a product to market, and that venture capital financing is related to the choice of product market strategy. Thus, venture capitalists are significantly involved in the activities of their portfolio companies. Hellman and Puri (2002) noted that venture capital financing is

also related to a variety of professionalisation measures, such as human resource policies, the adoption of stock option plans, the hiring of a vice president of marketing, and the replacement of the CEO.

Venture capital backed initial public offerings. The financial economics stream of venture capital research has notably focused on examining initial public offerings, potentially because the IPO enables the application of the IPO anomaly and efficient market hypotheses, and because share price data are easily available from the IPO onwards. New ventures are also valued for the first time in a competitive marketplace at the time of the IPO. Barry *et al*. (1990), Megginson and Weiss (1991), Lerner (1994a), Gompers (1996), Gompers and Lerner (1998), Lin and Smith (1998), and Gompers and Lerner (1999d) have published the key papers concerning IPO underpricing and the venture-capital backed IPO as an event. Venture capital backed IPOs suffer from smaller underpricing because of the certification effect. Similarly, VC-backed IPOs perform better in the long run than non-VC-backed IPOs (Brav and Gompers, 1997; Jain and Kini, 2000). The general long-term underperformance of IPOs results mainly from small, non-VC-backed IPOs (Brav and Gompers, 1997). The presence of venture capitalists also improves the survival probability of IPO issuing firms (Jain and Kini, 2000).

Table 1 summarises the key refereed articles, books, and recent working papers on venture capital. The table does is not intended to be exhaustive. Rather, I have attempted to point out the most frequently cited and relevant pieces of research on venture capital in refereed academic journals and key books. In this classification, the financial economics stream includes the following journals that have published articles on venture capital: *Journal of Finance*, *Journal of Financial Economics*, *Review of Financial Studies*, *Journal of Business*, *Financial Management*, *RAND Journal of Economics*, *Journal of Law and Economics*, *Journal of Banking and Finance*, *Journal of Corporate Finance*, *Journal of Business Finance and Accounting*, and *Accounting and Business Research*. The *Journal of Private Equity* is not included in the list because of its less formal, practitioner nature. *Venture Capital: An International Journal of Entrepreneurial Finance* is also omitted because this journal is not yet included in the Social Sciences Citation Index. The entrepreneurship and management stream includes the *Administrative Science Quarterly*, *Academy of Management Journal*, *Strategic Management Journal*, *Management Science*, *Journal of Business Venturing*, *Journal of Management Studies*, *R&D Management, International Small Business Journal,* and *Omega*. Articles published in *Frontiers of Entrepreneurship Research* are not included in this summary unless they have been published in one of the refereed journals. The "sociology and other" column in Table 1 attempts to capture other venture capital articles relevant to this dissertation that have appeared in journals not belonging to the two mainstreams of venture capital research.

Table 1 Refereed journal articles, selected books, and recent working papers on venture capital

JF = Journal of Finance, JFE = Journal of Financial Economics, RFS = Review of Financial Studies, JB = Journal of Business, FM = Financial Management, RAND = RAND Journal of Economics, JLE = Journal of Law and Economics, JBF = Journal of Banking and Finance, JBFA = Journal of Business Finance and Accounting, JCF = Journal of Corporate Finance, NBER = National Bureau of Economic Research, ASQ = Administrative Science Quarterly, AMJ = Academy of Management Journal, SMJ = Strategic Management Journal, MS = Management Science, JBV = Journal of Business Venturing, JMS = Journal of Management Studies, ISBJ = International Small Business Journal, AJS = American Journal of Sociology, EJOR = European Journal of Operational Research, OM = Omega, RDM = R&D Management, WP = Working paper.

Topic / Stream	Financial economics	Entrepreneurship and management	Sociology and other
Review articles and books on VC	Sahlman (1990, *JFE*) Barry (1994, *FM*) Wright and Robbie (1998, *JBFA*) Gompers and Lerner (2000) Gompers and Lerner (2001)	Timmons and Bygrave (1986, *JBV*) Bygrave and Timmons (1992) Bygrave *et al.* (1999)	
Relationship between VC and limited partners	Sahlman (1990, *JFE*) Gompers and Lerner (1996, *JLE*) Black and Gilson (1998, *JFE*) Gompers and Lerner (1999a, *JFE*)	Gifford (1997, *JBV*)	
VC investment process	Sahlman (1990, *JFE*) Fried and Hisrich (1994, *FM*) Gompers (1995, *JF*)	Tyebjee and Bruno (1984, *JMS*) MacMillan *et al*. (1985, *JBV*) MacMillan *et al*. (1987, *JBV*) Rea (1989, *JBV*) Hall and Hofer (1993, *JBV*) Rosman and O'Neill (1993, *JBV*) Chua and Woodward (1993, *JBV*) Rah *et al*. (1994, *JBV*) Steier and Greenwood (1995, *JMS*) Muzyka *et al*. (1996, *JBV*) Boocock and Woods (1997, *ISBJ*) Shepherd (1999, *MS*) Zacharakis and Meyer (1998, *JBV*) Zacharakis and Meyer (2000, *JBV*) Shane and Cable (2002, *MS*)	Siskos and Zopounidis (1987, *EJOR*)
Governance, control, and VC – entrepreneur agreements	Sahlman (1990, *JFE*) Admati and Pfleiderer (1994, *JF*) Lerner (1995, *JF*) Trester (1998, *JBF*) Bergemann and Hege (1998, *JBF*) Hellman (1998, *RAND*) Fenn and Liang (1998, *JBF*) Baker and Gompers (2000, WP) Kirilenko (2001, *JF*)	Bruno and Tyebjee (1985, *JBV*) Ruhnka and Young (1987, *JBV*) Dean and Giglierano (1990, *JBV*) Bowden (1994, *JBV*) Sapienza and Gupta (1994, *AMJ*) Fiet (1995, *JMS*) Barney *et al*. (1996, *JBV*) Sapienza and Korsgaard (1996, *AMJ*)	
Syndication of VC investments	Lerner (1994b, *FM*)	Bygrave (1987, *JBV*) Bygrave (1988, *JBV*) Brander *et al*. (1999, *WP*) Lockett and Wright (2001, *OM*)	Sorenson and Stuart (2001, *AJS*) Anand and Piskorski (2001, WP)
Risk, return, and valuation in VC	Huntsman and Hoban (1980, *FM*) Gompers and Lerner (2000, *JFE*) Kirilenko (2001, *JF*)	Ruhnka and Young (1991, *JBV*) Seppä and Laamanen (2001, *RDM*) Cochrane (2001, WP) Manigart *et al*. (2002, *JBV*)	
Investor value-added in VC-backed firms	Gompers and Lerner (1999c, *NBER*) Hellman and Puri (2000, *RFS*) Hellman and Puri (2002, *JF*)	Rosenstein (1988, *JBV*) MacMillan *et al*. (1988, *JBV*) Gorman and Sahlman (1989, *JBV*) Sapienza (1992, *JBV*) Rosenstein *et al*. (1993, *JBV*) Sapienza *et al*. (1996, *JBV*) Barney *et al*. (1996, *JBV*)	

Table 1 (continued)

Certification by VCs; VC prominence and reputation	Barry *et al*. (1990, *JFE*) Megginson and Weiss (1991, *JF*) Gompers (1996, *JFE*) Gompers and Lerner (1998, *JF*)	Amit *et al*. (1998, *JBV*) Stuart *et al*. (1999, *ASQ*)	Podolny and Feldman (1997, WP) Podolny (2001, *AJS*)
VC-backed initial public offerings; IPO event	Barry *et al*. (1990, *JFE*) Megginson and Weiss (1991, *JF*) Lerner (1994a, *JFE*) Gompers (1996, *JFE*) Gompers and Lerner (1998, *JF*) Lin and Smith (1998, *JCF*) Gompers and Lerner (1999d, *JLE*) Baker and Gompers (2000, WP)	Stuart *et al*. (1999, *ASQ*)	
Performance of VC-backed companies; long-run performance of VC-backed IPOs	Brav and Gompers (1997, *JF*) Jain and Kini (2000, JBFA)	Ruhnka *et al*. (1992, *JBV*)	
Performance of VC firms		Brophy and Guthner (1988, *JBV*) Chiampou and Kallet (1989, *JBV*) Bygrave (1989, *JBV*) Cochrane (2001, *WP*)	
Other		Elango *et al*. (1995, *JBV*) Freear and Wetzel (1990, *JBV*) Norton and Tenenbaum (1993, *JBV*) Florida and Kenney (1988, *JBV*) Manigart (1994, *JBV*)	

2.2 Asymmetric information, signalling, and certification

Summary of the theories

Asymmetric information refers to market information that certain economic actors possess but others do not. While the traditional neo-classical literature on economics generally assumes perfect markets and equally distributed, symmetric market information across actors, Akerlof (1970) demonstrated how the unequal distribution of information affects economic exchange. Using the market for used cars as an example, Akerlof showed how quality uncertainty can cause a market failure. In the market for used cars, and several generalisations of it, buyers face difficulties in verifying the quality of the cars they intend to buy from previous owners that have, in contrast, developed an accurate understanding on the actual quality of the cars. However, the owners of good-quality cars cannot convey their quality information reliably to the buyers. The owners of 'lemons', or cars of inferior quality, will claim their cars to be of good quality because they know that it is impossible for buyers to distinguish good cars from bad cars. Since all rational sellers claim their cars to be of good quality, the equilibrium price should be uniform across the market. However, because informational asymmetries prevent the buyers from distinguishing 'lemons', buyers require a discount that offsets their risk of *adverse selection* based on the average quality of cars in the market. Sellers, however, would be willing to place only 'lemons' for sale at that price. This causes the market to collapse: Akerlof (1970) shows that the result is a complete market failure, in which no transactions take place at any price.

In addition to the car market, Akerlof (1970) suggested several applications for his theory, including insurance, the job market, the cost of dishonesty, and the credit markets in underdeveloped countries. He also hypothesised that the theory could explain the existence of several economic institutions counteracting the adverse effects of informational asymmetries, such as guarantees, brand names, enterprise chains, licensing practices, and education. Akerlof's theory on asymmetric information has served as a basis for many further theories, including those of market signalling and certification, and was awarded the Nobel prize for economic sciences together with related work by A. Michael Spence and Joseph Stiglitz in 2001.

Signalling refers to activities by which the effects of informational asymmetries can be reduced. *Signals*, on the other hand, are the characteristics that reduce informational asymmetries. Signalling was first formulated as part of economic theory by Spence (1973; 1974), although Akerlof (1970) suggested several mechanisms that exist in real life because they reduce informational asymmetries between buyers and sellers. According to Spence's (1974:10) definition, the observable and alterable characteristics of an economic actor are potential or actual signals, depending on whether they actually affect others' quality assessments of the focal actor. Signals may include both elements that increase the amount of information other actors possess about the focal actor, and elements that alter their beliefs about the focal actor. As Spence (1974:1) writes, "*Market signals are activities or attributes of individuals in a market which, by design or accident, alter the beliefs of, or convey information to, other individuals in the market.*"

Spence (1973; 1974) formulated the signalling theory using the job market as an example, but the results are directly applicable to several other economic transactions. In the presence of neither signals nor observable but unalterable characteristics known as indexes, employers make their hiring decisions based on the unconditional probability that an applicant, drawn randomly from the applicant pool, will be productive. Such complete asymmetry of information between the employer and the applicant penalises applicants that are actually productive, and improves the position of applicants that are unproductive since the employer will pay all new hires the expected marginal product of the average applicant.

If signalling is possible (or indexes exist), the situation changes notably. Instead of estimating the unconditional probability of the applicant's being productive, the employer can estimate the conditional probability of employee productivity, given the observable characteristics of the applicant. Some of the potential signals may turn out to have an impact on the conditional probability estimate of productivity that the employer makes on the basis of past experience. For example, an employer would provide applicants with a high education level a higher level of salary if the employer's previous experience indicated that high education yielded higher productivity. After observing the true productivity of the new hire, the employer would adjust his assessment of the effect of education on the conditional probability of an applicant being productive. As a

result, productive applicants have an incentive to convey signals of their actual quality to the employer in order to maximise their pay.

However, there are conditions affecting the ability to signal. In order to be actual, i.e. reliable and effective, signals must fulfil two conditions (Spence 1974: 15). Firstly, signals must be costly to adjust. If there were no costs, all actors would adjust their signals to yield the maximum gain, and signals would have no informational content. Secondly, the adjustment cost must be negatively correlated with actual quality (productive capability in the context of the job market). Higher-quality actors should be able to adjust their signals at a lower cost than low-quality actors. Spence (1974: 18-26) shows that the negative correlation between adjustment costs and actual quality is a necessary but not a sufficient condition for signalling to take place. For signalling to be effective, it is further required that a sufficient number of signals within the appropriate cost range of signalling exists (Spence 1974: 26).

Signalling has been a popular topic in the finance literature because informational asymmetries between buyers and sellers are particularly pronounced in capital markets. Entrepreneurs and existing shareholders may possess superior information about their firm in comparison with prospective outside investors – in the same way as Akerlof's (1970) car-sellers with regard to their cars. Similarly, borrowers know their willingness and ability to pay back the loan better than lenders. However, *moral hazard* prevents both firm insiders and borrowers from conveying their inside information reliably to the market. There may be substantial returns on dishonestly overstating the quality of the firm's future prospects or the borrower's ability to pay back the loan, and the verification of the true characteristics of the firm or the borrower by outside parties may be costly or impossible.

Leland and Pyle (1977) are frequently cited for their initial formulation of a signalling hypothesis for the debt market. Entrepreneurs face great difficulties in conveying their private information about the quality of their project in the market because they have an incentive not to do so – they face the moral hazard problem. Although the information that entrepreneurs can convey does not fulfil the conditions of a signal, the actions of entrepreneurs can be observed and utilised as signals of the project's quality. In particular, Leland and Pyle (1977) demonstrated that the willingness of entrepreneurs to invest in their own project while raising debt produces an actual signal of the true quality of the project. Lenders will place a value on the project that reflects the information transferred by the signal. Signalling is reliable because entrepreneurs need to take larger equity positions in their own firms than they would if information transfer were possible, and thus face additional costs.

Financial intermediaries that provide market participants with objective information could, in principle, reduce the adverse effects of asymmetric information in the market. However, intermediaries that evaluate entrepreneurs' projects also face a moral hazard problem because their evaluation actions are unobservable to the market, and because

honest mistakes in evaluation are possible. Intermediaries may thus have an incentive not to use as many resources in information production as they claim to have used. Campbell and Kracaw (1980) argued that a financial intermediary can mitigate this moral hazard problem by investing its own wealth in the project. Intermediation alone does not resolve the problems of informational asymmetries and moral hazard. Rather, a sufficient capital outlay of the intermediary's own wealth in the project is required to make cheating sub-optimal.

Further studies have extended the basic framework of financial intermediation and informational asymmetry. Motivated by Leland and Pyle (1977) and Campbell and Kracaw (1980), Chan (1983) showed how informed intermediaries increase the welfare of investors by inducing entrepreneurs to offer high-return projects. Myers and Majluf (1984) demonstrated that, together with other issues, and consistent with informational asymmetries, issuing shares when management has inside information results in a fall in the share price. Insiders have information that outside investors do not have, which enables insiders to exploit situations where outsiders may have overestimated the future cash flows to be received by investors in a new issue.

Grinblatt and Hwang (1989) presented a generalisation of Leland and Pyle (1977). Since issuers have more information about the true future cash flows of the firm, firms should signal both the expected value and the risk of their projects in initial public offerings. In order to do so, firms convey an additional signal, offer underpricing, in addition to the ownership signal of Leland and Pyle (1977). Welch (1989) modelled how high-quality firms underprice their IPOs in order to obtain a higher price in a subsequent seasoned offering. These firms use underpricing as a signal of the actual quality of the firm. Low-quality firms, on the other hand, must invest in mimicking high-quality firms, and with some probability their mimicking is revealed between the IPO and the subsequent seasoned offering. Underpricing by truly high-quality firms can then add sufficient signalling costs to these imitation cost to induce low-quality firms to reveal their true status voluntarily.

Gale and Stiglitz (1989) demonstrated that the traditional IPO signalling models (Leland and Pyle, 1977; Grinblatt and Hwang, 1989) break down if insiders are allowed to sell equity more than once. Future possibilities of selling equity allow the firm to cover the costs of signalling falsely in the beginning. Thus, it is very difficult, if not impossible, for company insiders to signal the true quality of their firm in practice.

Certification refers to the ability of third parties to reduce the quality uncertainty about parties associated with them. Although the word 'certification' had already been used by Akerlof (1970) in the context of institutions counteracting informational asymmetries, the formal certification hypothesis of Booth and Smith (1986) established the concept in the context of financial markets and intermediaries. Booth and Smith (1986) modelled the ability of underwriters to certify the price of risky issues in markets characterised by asymmetric information between insiders and prospective outside investors. The

certification hypothesis derives from previous reputational signalling arguments that demonstrate how non-salvageable capital expenditures can serve as effective bonds to guarantee the quality of a firm's products (Klein and Leffler, 1981). Customers view non-salvageable investments as commitments to product quality. Similarly, Booth and Smith (1986) argue that prospective investors view the reputational capital commitment of the underwriter of a share issue as a commitment to the quality of the issue. In effect, investment banks 'lease' their brand name to the issuing firm to certify that the issue price reflects all inside information.

Booth and Smith (1986) additionally developed three key criteria for credible certification in the context of capital markets. Firstly, underwriters can become credible by accumulating reputational capital that is at stake at every subsequent issue. Secondly, new underwriters can build reputation by underpricing issues in the short run and absorbing the underpricing loss. Thirdly, reputable underwriters can protect their reputation by voluntarily making restitution purchases if the issue appears to be overpriced. Empirical evidence regarding the ability to certify the prices of initial public offerings supports these predictions. Johnson and Miller (1988) found that prestigious underwriters underprice less than non-prestigious bankers, that low initial returns are caused by differences in offering risk alone, and that the low initial returns exhibited by prestigious bankers are caused by the tendency to associate with less risky issues more frequently than non-prestigious bankers. Furthermore, Beatty and Ritter (1986) demonstrated that there exist a monotonic relationship between the expected underpricing of an initial public offering and the uncertainty of investors regarding its value. The more uncertain an offering, the more it will be underpriced. Additionally, they showed that investment bankers who "cheat" on issue pricing will lose either potential investors (too low underpricing) or potential issuers (too high underpricing).

Carter and Manaster (1990) established a methodology to measure underwriter reputation using a finer grid than that of Johnson and Miller (1988), and examined the effect of underwriter prestige on IPO underpricing and riskiness. They constructed a prominence score on the basis of the position of the investment banks' names in a large sample of IPO tombstone advertisements. The higher the name appeared, the more prestigious the bank was considered to be. Carter and Manaster (1990) found that their prestige score was significantly and negatively related to the extent of underpricing, and that more prestigious investment banks underwrote less risky issues. Thus, underwriter prominence represents a signal of quality to the market. Megginson and Weiss (1991) constructed an underwriter reputation measure based on the IPO market share of investment banks, and found that bank reputation is negatively related to the extent of underpricing of offerings. Furthermore, Carter *et al*. (1998) compared the performance of three different underwriter prestige measures. They found that underwriter prominence is not only negatively related to the underpricing of IPOs but also tends to reduce the long-run underperformance of IPO issuing firms.

Extending the contributions of these previous researchers, Chemmanur and Fulghieri (1994) developed a model of the impact of investment bank reputation on the cost of issuing shares, providing several important empirical implications. Firstly, the greater the reputation of an investment bank, the more effective it is in reducing the impact of information asymmetry in the equity market. Secondly, the greater the underwriter's reputation, the larger the fees charged. Thirdly, the proceeds to a firm selling equity, net of underwriter fees, increase with underwriter reputation.

Asymmetric information, signalling, and certification in the venture capital context

In the context of venture capitalists and their portfolio companies, informational asymmetries exist between existing shareholders and prospective outside investors principally in the same sense as asymmetries exist between the insiders and outsiders of any firm. Insiders are better informed of the actual future prospects of the venture, and rational outside investors recognise the possible incentives for the insiders to overstate the value of the firm when issuing equity.

Following the general theories developed to explain the role of financial intermediaries in resolving informational asymmetries between company insiders and outside investors, several authors have analysed the role of venture capitalists as such intermediaries. Barry *et al*. (1990) and Megginson and Weiss (1991) focused on the ability of venture capitalists to resolve informational asymmetries in initial public offerings. Because of their certification abilities, venture capitalists help firms to access higher-quality underwriters than firms without venture capitalist backing. Furthermore, as the certification hypothesis predicts, the underpricing of venture capital backed IPOs is significantly smaller than that of other IPOs. The market interprets the presence of venture capitalists as a signal of the actual quality of the issuing firm. Evidence from longer-term certification of venture capitalists also exists. Brav and Gompers (1997) analysed the long-run performance of venture capital backed and non-venture capital backed initial public offerings and found, consistent with the informational asymmetries hypothesis, that venture capital backed offerings outperform others in the long run.

Megginson and Weiss (1991) argued that venture capitalists can certify the price of initial public offerings because three essential criteria of credible certification are fulfilled. Firstly, VCs have reputational capital at stake because they are present in the IPO market on an on-going basis and because they continuously participate in a stream of direct equity investments in new ventures. VCs thus have an incentive to establish a trustworthy reputation in order to access the IPO market on favourable terms in the future. Furthermore, the greater a venture capital firm's perceived access to the IPO market, the more attractive it is to entrepreneurs. Similarly, a reputation for competence will allow venture capitalists to establish enduring relationships with limited partners that provide the funds to be invested.

The second criterion for credible certification is that the value of the venture capitalist's reputational capital must exceed the maximum possible benefit from false certification.

Sahlman (1990) documented that the very high returns of successful venture capitalists are directly related to the age, size, and historical performance of the VC fund, that successful VCs are able to establish profitable follow-on funds, and that the VC labour market is efficient with constant monitoring of individual performance. Consequently, Megginson and Weiss (1991) argued that investments in reputational capital are necessary for venture capitalists to stay competitive in the industry and capital markets.

Thirdly and finally, certification by venture capitalists should be credible because it is costly for the issuing firm to obtain the certificate, and because low information quality firms find certification more costly than high information quality firms. Venture capitalists require significant returns for their investments, depending on the stage of development, i.e. the information quality, of the venture. The annual required rates of return may be as high as 75% for early-stage ventures (Ruhnka and Young, 1991), whereas the required rate of return varies between 25% and 35% in the case of later-stage ventures. In addition, venture capitalists structure their deals so that a large part of the actual risk is shifted to the entrepreneur, thereby creating high costs of certification for low-quality firms. Such deal structures include, for example, the use of staged investment, the use of convertible preferred stock, and the option to replace the entrepreneur (Sahlman, 1990). In addition, low-quality firms find it difficult to obtain financing at all, because venture capitalists effectively evaluate and screen their prospective investments, and invest in a small percentage of initially recognised ventures.

Besides being a measure of the ability to certify IPO prices, the prominence of venture capital firms also affects their incentives to make lower-quality portfolio companies public. Gompers (1996) analysed the relationship between venture capitalist prominence and the incentives to make portfolio companies public, and found that young venture capital firms tend to rush for portfolio company IPOs in order to create initial reputation, and to demonstrate their ability to evaluate the quality of their portfolio companies.

Critiques might point out that informational asymmetries are not necessarily applicable to the venture capital setting because entrepreneurs might not actually have more information about the prospects of a new venture than experienced outside investors, especially in the early stages of the venture's development. Additionally, venture capitalists typically have an experience of several hundred evaluations of business proposals, which should make them more competent in evaluating a new business than a single entrepreneur with possibly inflated expectations for his idea. Quality uncertainty in Akerlof's (1970) sense might thus not exist.

While the argument of the evaluation experience of venture capital investors is probably true, it is unlikely that venture capital investors would have evaluation capabilities that could resolve all the informational asymmetries inherent in their investments. It is also likely that evaluation capabilities and thus certification abilities vary among venture

capitalists. Furthermore, the wide body of theoretical research on the role of financial intermediaries as parties resolving informational asymmetries in equity issues suggests that venture capitalists fulfil the criteria of a third party with a certifying ability. For example, the condition of committing one's own capital to the project (Campbell and Kracaw, 1980) is fulfilled because VCs invest significant amounts of their own capital in the new ventures that they attempt to certify (Gompers and Lerner, 2001: 108), and because venture capitalists' compensation is determined largely by the success of their investments (Gompers and Lerner, 1999a). Similarly, VCs have been demonstrated to acquire reputational capital (Gompers, 1996), and fulfil the key criteria for credible signalling (Megginson and Weiss, 1991).

Finally, the fact that venture capitalists have developed several mechanisms that attempt to resolve the informational asymmetries inherent in the investment process (Sahlman, 1990) supports the existence and importance of informational asymmetries in the venture capital context. These mechanisms include due diligence rights, staged investment, monitoring rights, and typically tight contractual arrangements that give several rights and options to venture capitalists. As a result, informational asymmetries are likely to play a significant role when new ventures with venture capitalist backing issue equity to outside investors.

2.3 Social structural view and social network theory

Summary of the theory

Theories of social networks have had important implications on how organisational activities are viewed by researchers and practitioners. Sociological theories were gradually introduced into organisational research in order to supplement the over-rationalised models of neo-classical economics that treated economic actors as atomic and fully rational (Granovetter, 1985; Gulati, 1995).

The view of markets as social structures emerged in the 1980s (e.g., White, 1981; Baker, 1984) as economic sociology began to argue that markets are not atomised and purely rational. One of the most cited pieces of work in economic sociology and the social structural view is the paper by Granovetter (1985), who regarded economic action as embedded in the social structure of the economic actors. The behaviour and institutions analysed in economic systems are constrained by ongoing social relations so that it is inappropriate to construe them as independent. While classical and neo-classical economics operate with an atomised, undersocialised conception of human action, and reformist economists tend to provide an over-socialised explanation of the same actions, the concept of embeddedness should avoid the extremes of both views. Furthermore, Granovetter pointed out that prior interactions with other economic actors are an important source of information about the quality of these actors, using illustrations such as "*the widespread preference for transacting with individuals of known reputation*", or actors resorting to "*trusted informants*". The interfaces between business

organisations and markets, and market relations, are also affected by social structures (Baker, 1990). As a result, corporations can directly manipulate the number and intensity of market ties with other organisations.

The social structural view emerged as a popular framework for analysing the formation of interorganisational alliances in the 1990s (Gulati, 1995). Prior alliances between firms create a network of ties, a social network in which most firms are embedded. This network acts as an important source of information about the reliability and capabilities of current and potential partners. As a result, social networks of prior alliances play an important role in shaping future alliance formation. Previously allied firms are likely to engage in further alliances with each other. Furthermore, by integrating both critical contingencies and social structural factors in the same model, Gulati (1995) united the network and resource dependence theories in the study of interorganisational ties.

By extending previous, dyad-focused research on strategic alliances, Gulati (1998) suggested that social networks are valuable conduits of information that provide both opportunities and constraints for firms, and have important behavioural and performance implications for their alliances. The more organisations can get information through the network, the better they perform and the more opportunities they have to establish new interorganisational relationships. Building upon the previous studies, Baum *et al*. (2000) examined the impact of alliance network composition on the performance of start-ups. While establishing alliances improves performance, variation in alliance network composition rapidly produces significant differences in firm performance.

Extending prior findings, Gulati and Gargiulo (1999) demonstrated that although organisations enter alliances with each other to access critical resources, they rely on information from the network of prior alliances to determine with whom they co-operate. The probability of a new alliance between two organisations increases with their prior mutual alliances, common third parties, and joint centrality in the alliance network. Furthermore, the higher the structural differentiation of the emerging network, the more organisational decisions about new partnerships are guided by endogenous network considerations rather than by exogenous factors such as access to resources (Gulati and Gargiulo, 1999). The crowding and prestige of an actor's network position also explain relationship formation (Stuart, 1998). Firms with previous alliances benefit from a form of relationship that provides them with privileged access to potential exchange partners.

Firm-level examinations of the role of network resources in determining alliance formation also indicate that accumulated network resources from prior alliances are influential in firms' decisions to enter new alliances (Gulati, 1999). However, prior relationships and positions do not provide the only explanation for the formation of new linkages. Ahuja (2000) argued and demonstrated that linkage-formation propensity is explained by simultaneously examining both inducement and opportunity factors. He

posited that three forms of accumulated capital – technical, commercial, and social – can affect a firm's capability to form linkages. Sociological dynamics can not fully explain network formation. Rather, resource-based motives are also significant.

In addition to the social structural view fostered by economic sociology, social status is one of the concepts of classic sociology that is relevant in the examination of the positions and networks of economic actors. In his classic article on the reward systems of science, Merton (1968) recognised the self-reinforcing positive effects of status. Eminent scientists tend to receive a disproportionate amount of credit for their contributions, and collaborative papers tend to produce a disproportionate degree of credit for the author with the greatest reputation. People remember primarily the author they are already familiar with from the past – the author with the higher status. This phenomenon, the 'Matthew Effect' (Merton, 1968), has since been documented in several contexts (e.g. Podolny, 1993).

Status is an important concept in economic exchange because greater actor status increases the utility derived from the association with or consumption of a good (Podolny, 1993). Status also acts as an indication of the quality of the actor. Furthermore, an actor's network of relations mediates the link between quality and status for two reasons. Firstly, the embeddedness of action in social relations can prevent contact between producers and consumers that could potentially change the latter's opinion of the former. For example, low-status goods may not at all be considered reasonable substitutes for high-status goods, and low-status producers cannot establish a contact with purchasers of high-quality goods. Secondly, social relations also mediate between status and quality because status flows through the interlinkages between organisations.

Furthermore, status is a function of market uncertainty (Podolny, 1994). Organisations become highly selective in their exchange relationships when uncertainty increases. In times of uncertainty, organisations are more likely to exchange with partners familiar from the past. When quality cannot be directly observed, economic actors increasingly rely on status as the signal of the underlying quality of the exchange partner. An increase in uncertainty thus causes organisations to enter into exchange relations with other organisations of similar status (Podolny, 1994).

Social power and centrality form the basis for the measurement of status. Cook and Emerson (1978) showed that power is an attribute of position in a network structure. Bonacich (1987) constructed a generalisation of network centrality measures that accounts for both power and centrality, depending on the symmetry or asymmetry of the interactions. Bonacich's measure soon became the standard centrality and status measure in sociology (Podolny, 1993).

The social structural view and social network theory in the venture capital context

In venture capital research, the social structural view and theories on social networks have been tested in the empirical context of investment syndication networks. In his analysis of the structure of U.S. venture capital syndication networks, Bygrave (1988) used network measures and methodology drawn from sociology. While his approach was not driven by the social structural view, the treatment of the group of syndication dyads as a network of embedded economic action (Granovetter, 1985) established the first link between venture capital research and social network theory.

The social structure of the network of venture capital firms significantly affects the formation of investment syndicates. Drawing on two competing theories – resource dependence and the social structural view – Anand and Piskorski (2001) tested whether the possession of financial resources or prior network position determines future network position. While peripheral venture capitalists found it difficult to syndicate with central venture capitalists except if they held considerable financial resources, central VCs could establish ties with other central firms despite limited monetary resources. Thus, central venture capitalists tended to maintain privileged positions even if they did not have attractive financial resources. The results of Anand and Piskorski (2001) support both the exogenous and the endogenous view of network formation. While central firms do not suffer the penalty of not possessing financial resources, and can sustain their positions because of endogenous network formation, peripheral firms can take advantage of exogenous network formation if they have attractive resources to exchange.

Adopting a status-based perspective, Podolny (2001) examined how the position of venture capital firms in the network of syndication relationships affects their choice of market segments. Whereas high status tends to drive venture capitalists towards less risky market segments, the presence of structural holes in the network implies a shift from low-risk to high-risk segments. Strategy choice and market behaviour are thus embedded in the network of syndication relationships. Interfirm networks also affect the spatial patterns of exchange in venture capital (Sorenson and Stuart, 2001). While information generally circulates within geographic and industry spaces, VCs that build axial positions in the network can more often manage investments in spatially distant companies.

2.4 Resource-based view of the firm

Summary of the theory

In her seminal work, Penrose (1959: 67) defined a firm's resources as "physical things a firm buys, leases, or produces for its own use, and the people hired on terms that make them effectively part of the firm." According to Penrose, the firm is a bundle of both physical and human resources that enable it to exploit its "productive opportunity". The growth of the firm depends on and is limited by its resources and the managerial competencies available to utilise the resource base.

The term "resource-based" was introduced by Wernerfelt (1984). He criticised the then dominant view of the firm as a collection of product-market positions, and argued that firms are instead a collection of resources. Similarly, Rumelt (1984) suggested that the combination of unique resources and relationships handled by the management determines a firm's competitive positioning.

However, resources are only those assets that will potentially generate economic benefit and competitive advantage for the firm, and thus resources should have four distinctive characteristics (Barney, 1991). Firstly, resources must be *valuable* to the firm, either in terms of lower input costs or higher prices of outputs. Secondly, resources must be *rare or firm-specific*. If resources are commonly held, they will not differentiate firms from one another, and thus would not provide competitive advantage. Thirdly, resources must be *imperfectly imitable* to sustain the competitive advantage in the long run. Imperfect imitability, or inelastic supply (Barney, 1991) can be achieved if resources are path dependent, causally ambiguous, or socially complex. Finally, resources must *not be substitutable*. If resources could be replaced using strategically equivalent substitutes, they would not provide competitive advantage. These factors imply that resources cannot be instantaneously developed. Rather, they require time to accumulate.

Although Barney's (1991) paper has become a key piece of research on the resource-based view, other authors have contributed to the initiation of the research stream after Wernerfelt (1984). Dierickx and Cool (1989) identified five factors that influence the substitutability and imitability of resources. Firstly, time compression diseconomies imply that it takes time to accumulate resources, and that a stream of investments of constant size in resource accumulation produces diminishing returns over time. Secondly, asset mass efficiencies are a source of competitive advantage because the possession of an initial stock of resources tends to enhance the accumulation of additional resources. Thirdly, assets may be interconnected so that the ability to accumulate resources depends on the level of other resource stocks. Fourthly, assets erode over time unless investment in keeping up the stock of resources is maintained. Finally, causal ambiguity makes it difficult to identify and replicate the process of accumulating the resource stock.

Further research on the resource-based view of the firm has extended the resource-based theory from inside the firm to interorganisational relationships, such as alliances (e.g. Das and Teng, 2000; Eisenhardt and Schoonhoven, 1996). The resource-based view has additionally served as a starting point for several other related streams of research, such as the knowledge-based view (e.g. Grant, 1996).

Resource-based view in the venture capital context

There is relatively little formal empirical literature on the resource-based view in the venture capital context. From the portfolio company perspective, the research stream focusing on the *value added* of venture capitalists is perhaps the most closely related area of venture capital research (MacMillan *et al.*, 1988; Gorman and Sahlman, 1989;

Rosenstein *et al*., 1993; Sapienza, 1992; Sapienza *et al*., 1996; Hellman and Puri 2000; 2002). While these papers generally examine venture capitalists as financial institutions, and do not derive hypotheses explicitly from the resource-based view of the firm or from any other clearly identifiable theory base, the arguments of these papers clearly refer to resources as a competitive advantage.

The main question of the research stream on venture capitalists' value added is whether VCs add value in portfolio companies other than money. Money itself is a critical resource for portfolio companies, but research has considered venture capitalists to be active investors offering various value-adding services to their portfolio companies. These activities include monitoring financial and operational performance, recruitment of CEO and management, arranging financing from complementary sources, serving as a sounding board for the entrepreneur team, arranging incentive plans, providing access to auditors, lawyers, and investment banks, and setting company policies (MacMillan *et al*., 1988; Gorman and Sahlman, 1989; Rosenstein *et al*., 1993; Sapienza, 1992; Sapienza *et al*., 1996; Hellman and Puri, 2000; 2002). The value-adding activities clearly aim at providing resources or accelerating the accumulation of resources within portfolio companies. In particular, the role of venture capitalists in providing access to financial and human resources is stressed in the literature on the value added of venture capital firms.

There is even less literature focusing on venture capital *firms* from the resource-based perspective. Previous research has identified that venture capital firms need, in principle, three kinds of resources (Bygrave, 1987). Firstly, VCs need financial resources – the capital to be invested in the portfolio companies. The second necessary resource is a supply of potential investment targets, i.e. promising new ventures short of capital. Finally, the VC firm must have applicable human resources. It must find competent general partners and support staff to select and steer the portfolio companies. At various times, these resources may be abundant or in short supply.

In spite of the lack of formal resource-based research on venture capital firms, a number of studies have examined resource exchange in venture capital syndicates partly based on resource-based theory. Bygrave (1987; 1988) examined the syndication of venture capital investments using a resource dependence framework and resource-based arguments to analyse the formation of venture capital co-investment relationships. Bygrave (1987) found that the sharing of information and knowledge seems to be more important than the sharing of financial resources as a reason for syndication. This is fostered by the need to specialise in investments of a certain stage of development or industry in order to add value to the investments.

Anand and Piskorski (2001) examined the role of financial resources and network positions in the formation of venture capital syndicates. While peripheral firms need financial resources to establish co-operative relationships with very central firms, other central firms can establish syndication relationships despite the possible lack of financial

resources. Anand and Piskorski (2001) argue that these findings support the social structural view of venture capital syndication, but point out that the underlying reason for establishing co-operative relationships must to some extent be the parties' ability to provide resources to each other.

2.5 Real options

Summary of previous research

The financial option-pricing theory by Black and Scholes (1973) solved many of the difficulties in pricing financial derivatives. Soon after these findings, similarities between financial derivative contracts and real investment opportunities began to attract interest among researchers. Myers (1977) first identified the analogy between financial options and real options. Specifically, he noted that the equity of a company has similar characteristics to a call option. In effect, equity holders have a contingent claim on the firm's future cash flows.

The first applications of real option valuation were natural resource investments (Tourinho, 1979). These applications provide a sound basis for applying real options theory, since the market prices of natural resources are readily observable, and the stochastic process of the market prices can be estimated using ideas from financial options in a straightforward way. Brennan and Schwartz (1985) continued in this application area by valuing gold mine reserves.

As the research stream started to expand, option pricing was connected to capital budgeting, and models for the valuation of different types of real options began to arise. McDonald and Siegel (1985; 1986) modelled abandonment options and options to defer investment. A variety of different real options were identified and analysed during the 1980s. Trigeorgis (1993b) summarised the research into different types of real options by dividing real options into six categories. In principle, companies face options to defer, options to stage investment, options to alter operating scale, options to switch, and options to grow. Finally, according to Trigeorgis, there may be multiple real options that interact. These options are described in more detail in Table 2, which also contains the major contributors to the specific research fields.

During the late 1980s and early 1990s, the valuation of natural resource investments remained an important area of real option research (Paddock *et al.*, 1988; Morck *et al.*, 1989; Kemna, 1993). However, several new application areas were developed, such as real estate (Stulz and Johnson, 1985; Williams, 1993; Quigg, 1993; 1995), research and development (Morris *et al.*, 1991; Newton and Pearson, 1994), mergers and acquisitions (Hathaway, 1990; Smith and Triantis, 1995), and manufacturing (Aggarwal, 1991). The options approach also received initial acceptance in management research (Kogut, 1991).

Table 2 Common real options (partly adapted from Trigeorgis, 1993b and Lander and Pinches, 1998)

Category	Description	Important in	Selected references
Option to defer	Management holds a lease on valuable land or resources. It can wait to see if output prices justify constructing a building or plant, or developing a field.	All natural resource extraction industries; real estate development; farming; paper products	Tourinho, 1979; Bernanke, 1983; Titman, 1985; McDonald and Siegel, 1986; Lee, 1988; Paddock *et al.*, 1988; Pindyck, 1991; Ingersoll and Ross, 1992; Dixit and Pindyck, 1994; Kulatilaka, 1995; Quigg, 1995; Lee, 1997; McGrath, 1997
Time to build option (staged investment)	Staging investment as a series of outlays creates the option to abandon the enterprise in mid-stream if new information is unfavourable. Each stage can be viewed as an option on the value of subsequent stages, and valued as a compound option.	All research and development intensive industries, especially pharmaceuticals; long development capital-intensive projects, e.g. large-scale construction or energy-generating plants; start-up ventures	Baldwin, 1982; Majd and Pindyck, 1987; Carr, 1988; Trigeorgis, 1991; Sahlman, 1993; Teisberg, 1993; Trigeorgis, 1993a; Kulatilaka, 1995; Smit, 1997
Option to alter operating scale	If market conditions are more favourable than expected, the firm can expand the scale of production or accelerate resource utilisation. Conversely, if conditions are less favourable than expected, it can reduce the scale of operations. In extreme cases, production may temporarily halt and start up again.	Natural resource industries such as mine operations; facilities planning and construction in cyclical industries; fashion apparel; consumer goods; commercial real estate	Brennan and Schwartz, 1985; McDonald and Siegel, 1985; Kulatilaka, 1995; Pindyck, 1988; Kogut, 1991; Mauer and Triantis, 1994
Option to abandon	If market conditions decline, management can abandon current operations permanently and realise the resale value of capital equipment and other assets in second-hand markets.	Capital-intensive industries, such as airlines and railways; financial services; new product introductions in uncertain markets	Bonini, 1977; Howe and McCabe, 1983; McDonald and Siegel, 1986; Kulatilaka, 1995; Berger *et al.*, 1996
Option to switch (e.g. outputs, inputs, or risky assets)	If prices or demand change, management can change the output mix of the facility. Alternatively, the same outputs can be produced using different types of inputs.	Output shifts: Any good sought in small batches or subject to volatile demand, e.g., consumer electronics, toys, specialty paper, machine parts and cars Input shifts: All feedstock-dependent facilities, e.g., electric power, chemicals, crop switching and sourcing	Margrabe, 1978; Stulz, 1982; Baldwin and Ruback, 1986; Kulatilaka, 1995; Ikenberry and Vermaelen, 1996
Growth options	An early investment is a prerequisite or link in a chain of interrelated projects, opening up future growth opportunities.	All infrastructure-based or strategic industries, especially high-tech, research and development, or industries with multiple product generations or applications; multinational operations; strategic acquisitions	Myers, 1977; Pindyck, 1988; Brealey and Myers, 1991; Chung and Charoenwong, 1991; Kulatilaka, 1995; Smith and Triantis, 1995; Willner, 1995; Berk *et al.*, 1999
Multiple interacting options	Real-life projects often involve a 'collection' of various options, both upward-potential enhancing calls and downward-protection put options present in combination. Their combined option value may differ from the sum of separate option values; that is, they interact.	Real-life projects in most industries discussed above	Trigeorgis, 1993a; Brennan and Schwartz, 1985; Childs *et al.*, 1998; Laamanen, 1999

From the mid-1990s onwards, research in real options and the valuation of investments under uncertainty grew rapidly (Dixit and Pindyck, 1994). The research on real options reached a critical mass with several models for different theoretical purposes and applications, such as performance comparisons of different valuation paradigms, option interdependencies, strategic options, and infrastructure options (Trigeorgis, 1995; 1996). However, practical implementation issues have been ignored to a large extent in the literature on real options. Researchers have largely focused on developing sophisticated mathematical formulations of complicated valuation models, of which not all are likely to be feasible in practice. The complexity and mathematical rigour in modelling tends to inhibit many of the reverse-engineering possibilities that are highly valuable to real-life decision-makers (Lander and Pinches, 1998).

Real options in the venture capital context

Previous research has applied real options to three areas in venture capital: venture capital contracting, related agency conflicts, and valuation. Firstly, venture capital contracts include several option-like features that aim at increasing the value of the contract compared to a situation where no such features exist. Sahlman (1993) listed three important contractual options typically included in venture capital agreements with staged capital commitments. Firstly, by staging capital commitment, the venture capitalist gains an option to abandon the venture at each stage. Secondly, the venture capitalist gains an option to re-value the project at each stage as new information arrives. Thirdly, the venture capitalist gains an option to increase the amount of capital committed at each stage. Sahlman (1993) also shows that the series of options to abandon creates a win-win situation for the entrepreneur and the venture capitalist, as compared to up-front financing. The series of options thus creates additional value to the contract. Gompers (1995) provides broad empirical evidence regarding the existence of the option to abandon.

Secondly, direct entrepreneur – venture capitalist agency conflicts have been analysed using options theory. Bergemann and Hege (1998) identified that the ownership share of the entrepreneur reflects the value of a real option. The option is based on the control of funds. Since the entrepreneur controls the allocation of funds invested in the company, the allocation process is largely unobservable to the investor. Thus, the entrepreneur may use the funds, for example, for his private purposes. Bergemann and Hege (1998) argued that the solution to this agency conflict must take into account the inter-temporal incentives for the entrepreneur. In contracting, the entrepreneur must be compensated for both the foregone private benefits and for the downgrading of his expectations about the future of the project. The longer the experimentation horizon, the larger is the option value of the diversion.

Thirdly, Willner (1995) made one of the only attempts to model the value of a start-up firm utilising option-pricing theory. He pointed out that many start-ups have the characteristics of growth options but that traditional option methodology is inadequate

for valuing them. Willner (1995) criticised the assumption of a continuous cash flow generation process behind the traditional option methodology, and presented a jump model for the pricing of start-up companies. However, Willner's (1995) assumption of a simple exponential growth process with upward jumps may be considered somewhat restrictive. Additionally, there is little empirical evidence regarding the performance of the model in practice.

3 SUMMARY OF THE ESSAYS

3.1 Valuation of venture capital investments: Empirical evidence[1]

The first essay of this dissertation constructs and tests a binomial option-based pricing model for staged venture capital investments. Valuing high-growth, high-uncertainty firms is a major challenge faced by most venture capital firms. A typical venture capital valuation procedure involves an analysis of potential future cash flows, an analysis of comparative firms' stock prices or IPO performance, and an analysis of the price-to-earnings ratio or the price-to-sales ratio of the venture. Yet, the resulting valuations of these growth firms often seem to defy the common wisdom on growth firm valuation – being exceptionally high during the boom years of 1998 – 2000, and slumping down extremely rapidly after the collapse of share prices in the technology sector in March 2000.

In general, the theory of investment has made significant advances and enables elaborate analyses of real options and option interactions (e.g. Dixit and Pindyck, 1994; Trigeorgis, 1996; Brennan and Trigeorgis, 2000). Even the uncertainty inherent in venture capital investments has been conceptually shown to be decomposable into a set of options (Sahlman, 1990). Yet, the lack of empirical evidence showing the practical applicability of option-based pricing models would seem effectively to inhibit their adoption in practice. To address these questions, the first essay constructs a simple binomial option-based pricing model for staged venture capital investments, tests the model using actual valuation data, and analyses the risk-return structure of venture capital investments using the model.

The empirical sample of the essay consists of 597 venture capital financing rounds made in 176 U.S. venture capital backed companies that were listed on a U.S. stock exchange in 1998 and 1999. The data set is compiled from the Venture Economics Disbursements database, the SDC New Issues database, SEC IPO prospectuses, and the U.S. Federal Reserve Bank of Chicago interest rate database. The statistical tests are conducted using Ordinary Least Squares (OLS) regression models.

[1] This essay was originally published in *R&D Management* 31(2), 2001, pp. 215-230. Reprinted with the permission of Blackwell Publishers.

The essay provides the following key results. Firstly, the binomial option-based pricing model constructed in the essay is found to be consistent with previous knowledge of the risk-return structure of VC investments. The implied volatility and the risk of VC investments decreases as ventures reach higher stages of development. Secondly, the predictive power of the binomial option-based model is found to be marginally better than that of corresponding traditional models that use risk-adjusted rates of return and actual success probabilities. The risk-neutral valuation estimates seem to be relatively unbiased, since the mean and median estimation errors are found to be small. Nevertheless, the variance of the estimation error is still considerable, which is consistent with the 'common sense' observation that venture capital investments often result in extreme outcomes.

The main implication of the essay is that option-based pricing models seem to have relevance in venture capital applications. Even the simple risk-neutral binomial model of the essay can provide a useful methodology for analysing the risk-return structure of these investments. An important implication of this paper for researchers is that the risk and implied volatility associated with privately held companies indeed decrease as they reach higher stages of development. Thus, pricing models that assume constant volatility are not likely to be applicable in venture capital or R&D project settings. However, the results of the essay demonstrate that the problems of valuing new, high-growth companies are difficult to solve merely by constructing new valuation models. The uncertainty about the input parameters required to assess the value of a new venture using any valuation framework remains, nevertheless, extremely high.

3.2 Certification and bargaining power in venture capital: The impact of investor prominence on company valuations

The second essay demonstrates how the prominence of venture capital firms affects the valuations of new ventures. According to theories of asymmetric information and certification, prominent investors should be able to reduce the quality uncertainty between new ventures and outside investors. Reducing quality uncertainty implies that outside investors should be willing to pay more for ventures that have certifying investors, and that certifying investors should possess bargaining power over the price of the venture's shares when investing for the first time in the venture.

In spite of the wide body of literature on the price-certifying role of third-party specialists, previous research has mainly focused on the initial public offering and the public markets (Beatty and Ritter, 1986; Booth and Smith, 1986; Carter and Manaster, 1990; Megginson and Weiss, 1991; Gompers, 1996; Carter *et al.*, 1998). It has largely ignored the venture capital setting and the highly uncertain private financing stages, although certification should be most valuable when only little public and symmetric information about the investment targets is available. Apart from the compensation of

issue underwriters, previous research also lacks evidence regarding the bargaining power of third parties over the price of the certification they provide.

Drawing on theories of asymmetric information, signalling, and certification, the second essay addresses these two key questions. Firstly, it tests whether the prominence of existing insider venture capitalists affects the valuation of the venture in subsequent financing rounds when new outside investors invest in the venture (certification). Secondly, the paper tests whether the prominence of new outside investors affects the price they need to pay for the shares of the venture (bargaining power).

The essay is based on a large data set of 32,311 financing rounds in 13,048 U.S. venture capital backed companies between 1990 and 2000. The data set is gathered from the Venture Economics' Disbursements database, the Venture Economics' Fund Commitments database, the Securities Data Corporation's New Issues database, and Securities and Exchange Commission's IPO prospectuses. Venture capital valuations are analysed using both hedonic pricing models, where all price observations are regressed on a set of explanatory variables, and first differences of the venture valuations. The essay utilises full maximum likelihood Heckman sample selection models to overcome potential selection biases in the data set of venture capital valuations.

The results document that investor prominence has a significant effect on venture capital valuations. Consistent with the theoretic predictions, the essay shows that certification ability gives prominent venture capitalists bargaining power that they utilise when investing in ventures for the first time. Furthermore, the essay demonstrates that the prominence of existing venture capital investors improves valuations in future financing rounds.

The essay suggests and attempts to eliminate several alternative explanations for the results, including winner-picking by prominent venture capitalists, tangible value-adding activities of the venture capitalists instead of certification only, and the period of the study. Most importantly, the essay shows that the impact of investor prominence is contingent on uncertainty, eliminating the possibility that *only* value-adding capabilities would explain the findings. More uncertain ventures gain more benefit from the presence of prominent insider investors, and are willing to offer larger discounts to new, prominent outside investors than to less uncertain ventures. Because the effect of prominence is contingent on uncertainty, prominent investors have certification abilities that affect venture valuations. The findings do not, however, argue for or against the potential tangible value-adding capabilities of venture capital investors. Rather, these capabilities are likely to be complementary to the certification phenomenon documented in the results.

In addition to the contributions on the theories of asymmetric information and certification in the context of venture capital, the essay makes a number of methodological and practical contributions. Firstly, the essay provides an approach for measuring the prominence or reputation of venture capitalists. IPO market share is a

consistent measure of prominence, being strongly correlated with investment experience, and slightly less strongly with the age of the venture capital firm. Secondly, the results imply that prominent venture capitalists reduce the cost of follow-up financings. Finally, the results also suggests that investor prominence can and will be leveraged in valuation negotiations with entrepreneurs.

3.3 Syndication and the efficiency of venture capital firms

The third essay sheds light on how syndication relationships affect the performance, and thus the prominence, of venture capital firms. More specifically, the essay examines the relationship between syndication and the efficiency of venture capital firms. While previous research has extensively examined the reasons for establishing syndication relationships, significantly fewer insights are provided into the impact of syndication on the venture capital firm and on its ability to generate returns on its investments. To provoke a structured discussion on the actual benefits and drawbacks of venture capital syndication, this paper sets out to examine if and how syndication relationships affect the efficiency of venture investors. The essay draws on six previously identified potential motives for syndication, particularly the value-added motive (Bygrave, 1987; Brander *et al.*, 1999), the decision-making motive (Lerner, 1994b), the information-sharing motive (Bygrave, 1987), and the window dressing motive (Lerner, 1994b).

The hypotheses of the essay predict that syndication has an impact on the efficiency of venture capital firms. Essentially, it is posited (1) that the frequency of syndicating investments improves the venture capital firms' efficiency in creating public companies from portfolio companies, and their efficiency in completing deals, (2) that the diversity of syndication relationships improves the venture capital firms' efficiency in creating public companies from their portfolio companies, but can either increase or decrease their efficiency in completing investments, and (3) that portfolio uncertainty intensifies the impact of the frequency and diversity of syndication on firm efficiency. Venture capitalists who appropriately manage their frequency of syndication and the diversity of their syndication relationships should be able both to complete more investments with a given amount of resources and time, and to create proportionally more public companies from the companies that end up in their portfolio.

The essay is built upon an extensive longitudinal data set of the investments by the 100 largest U.S. venture capital firms between 1986 and 2000. The data set is compiled from over 50,000 investments recorded in the Venture Economics database, hand-collected data from the past issues of *Pratt's Guide to Venture Capital Sources*, and IPO data from Securities Data Corporation's New Issues database. The analysis of the essay utilises time series – cross sectional generalised least squares (GLS) regression methods.

The results provide support for the hypotheses on the impact of syndication on the efficiency of venture capital firms. The key lever of enhancing the 'hit rate', or the efficiency in creating public companies from the portfolio companies, appears to be the

diversity of syndication relationships. Furthermore, investors who frequently engage in syndicates can leverage their syndication partners to increase their efficiency in completing deals. Additionally, the results demonstrate that uncertainty moderates the relationship between syndication and the efficiency in creating public companies. The more uncertain the venture capital firm's investment portfolio, the more syndication affects the efficiency of the firm. The positive contingency on portfolio uncertainty also allows to reject the window dressing hypothesis as a potential alternative reason for the findings.

The essay has several important implications. Firstly, the results provide understanding on proper syndication strategies for venture capitalists. Both the diversity and frequency of syndication relationships appear important in terms of efficiency especially when uncertainty is high. Diversity, however, seems to be more powerful in explaining efficiency in the creation of public companies from the portfolio companies. Diversity improves the "hit rate" of venture capitalists. Thus, having a diverse set of syndication partners is a potential success factor in venture capital investing especially in the case of early-stage investments.

Secondly, venture capitalists can use syndication as a vehicle to adjust their deal completion efficiency. Frequent syndication with a limited number of syndication partners results in a larger number of deals being completed within a given period. The "throughput" of the firm thus increases with the frequency of syndication. However, as the diversity of syndication relationships increases, deal completion rates and the "throughput" may start to decrease, although our results suggest that the effect is not significant. Nevertheless, venture capitalists should attempt to balance their frequency of engaging in investment syndicates and the diversity of their syndication relationships to find an optimal combination of impact on the "hit rate" and the "throughput" of their firm.

3.4 How the rich become richer in venture capital: Firm performance and position in syndication networks

The fourth essay examines how positioning in syndication networks affects the performance of venture capital firms, and how these firms gain central positions in the network. Previous research has shown that both the resource-based theory of the firm and the social structural view predict that well-connected firms with central positions in collaborative networks should perform better than peripheral firms (Ahuja, 2000). The theories posit that venture capitalists that have gained a central position in the syndication network should, consequently, be able to achieve above-average performance as a result of resource-based or social structural benefits. However, the theories provide different explanations on what causes firms to obtain central positions. The essay focuses on testing two competing hypotheses in order to examine the causality of the hypothesised relationship between firm performance and network position. On

one hand, the social structural hypothesis implies that prior position be the major determinant of future position. On the other hand, resource-based reasoning suggests that past performance should certify the resources of the focal firm, attract exchange partners, and improve the network position of the focal firm.

The essay is built upon an extensive longitudinal data set of the investments by the 100 largest U.S. venture capital firms between 1986 and 2000. The data set is compiled from over 50,000 investments recorded in the Venture Economics database, hand-collected data from the past issues of *Pratt's Guide to Venture Capital Sources*, and IPO data from Securities Data Corporation's New Issues database. The analysis of the essay utilises distributed lag generalised least squares (GLS) regression methods with distributed lag constructions of the variables. The longitudinal sample also allows tests of causality to be performed (Granger, 1969).

The results of the essay demonstrate that network positions contribute to actual performance, and that past positions constitute a dominant determinant of future positions. Firms in central network positions increase their market share of portfolio company initial public offerings in subsequent years. However, while past performance is strongly associated with subsequent performance, prior network positions tend to determine current positions. Past performance is not associated with subsequent position centrality. Instead, past network position appears to represent a significant determinant of both subsequent performance and subsequent network position. Changes in the number of general partners are found to contribute to changes in existing network positions, initially suggesting that the personal networks of individual partners may transform into firm networks over time after partner acquisition.

The results have several implications. Firstly, the essay supports the social structural view of inter-firm co-operative networks. The results suggest that venture capital firms gain centrality by other means than signalling the quality of their resources, and that the structure of venture capitalist syndication networks is rigid, and involves high barriers to success for newcomer firms. Furthermore, the results suggest that new venture capital firms may find it rewarding to seek central network positions by actively building exchange relationships through syndication.

Table 3 provides a summary of the four essays of this dissertation, and Figure 2 illustrates the positioning of the essays in the venture capital industry.

Table 2 Summary of the essays

	Essay 1	Essay 2	Essay 3	Essay 4
Title	Valuation of venture capital investments: Empirical evidence	Certification and bargaining power in venture capital: The impact of investor prominence on company valuations	Syndication and the efficiency of venture capital firms	How the rich become richer in venture capital: Firm performance and position in syndication networks
Key questions	What is the risk-return structure of venture capital backed companies like? How well does a binomial pricing model perform in the valuation of such companies?	Can prestigious venture capitalists certify the quality of new ventures? Do prestigious venture capitalists utilise their bargaining power over the valuation of new ventures?	Do the frequency of syndication and the diversity of syndication relationships affect the efficiency of venture capital partnerships? Does uncertainty moderate the impact of syndication on firm efficiency?	Does the network position of a venture capital firm affect its future performance? Does the quality of resources or prior network position explain the future network position of a venture capital partnership?
Theory base	Option-pricing theory	Theory of asymmetric information Signalling theory Certification hypothesis	Syndication theories	Social structural view vs. resource-based view of the firm
Focus	Portfolio company	Venture capital firm – portfolio company relationship	Venture capital firm	Venture capital firm
Unit of analysis	Financing round	Financing round	Firm-year observation	Firm-year observation
Research design	Quantitative empirical, cross-sectional	Quantitative empirical, longitudinal	Quantitative empirical, longitudinal	Quantitative empirical, longitudinal
Sample	597 valuation observations on U.S. venture capital backed companies, 1998 – 1999 Data comprises 421 valuations from venture capital financing rounds and 176 IPO valuations	32,311 traditional venture capital financing rounds in U.S. ventures, 1990 – 2000 Data includes 5,679 rounds with disguised valuation data	100 largest U.S. independent private venture capital partnerships, 1986 – 2000 Data comprises 10,057 ventures and 29,967 financing rounds (54,700 rounds in constructing network measures)	100 largest U.S. independent private venture capital partnerships, 1986 – 2000 Data comprises 10,057 ventures and 29,967 financing rounds (54,700 rounds in constructing network measures)
Key methods	Descriptive quantitative methods; OLS regression	Heteroskedasticity-consistent full maximum likelihood Heckman sample selection regression	Maximum likelihood generalised least squares (GLS) regression with fixed effects	Maximum likelihood generalised least squares (GLS) regression with distributed lags and fixed effects
Main data sources	Venture Economics Disbursements database SDC New Issues database SEC IPO prospectuses U.S. Federal Reserve Bank of Chicago interest rate database	Venture Economics Disbursements and Fund commitments databases SDC New Issues database SEC IPO prospectuses	Venture Economics Firms, Fund commitments, and Disbursement databases SDC New Issues database SEC IPO prospectuses Past issues of Pratt's Guides to Venture Capital Sources General partners' résumés	Venture Economics Firms, Fund commitments, and Disbursement databases SDC New Issues database SEC IPO prospectuses Past issues of Pratt's Guides to Venture Capital Sources General partners' résumés

Table 3 (continued)

	Essay 1	Essay 2	Essay 3	Essay 4
Key results	1. The binomial option-based pricing model of the essay is consistent with previous knowledge on the risk-return structure of VC investments 2. The predictive power of the binomial option-based model is somewhat better than that of corresponding DCF models, but estimation errors are still large 3. The implied volatility (risk) of VC investments decreases as ventures reach higher stages of development	1. Prominent outside venture capital investors exercise bargaining power over the valuation of a venture when investing for the first time in it 2. Prominent venture capitalists that have an insider position in a venture resolve quality uncertainty over the venture, resulting in higher valuations by new outside investors 3. The more uncertainty, the more valuable is the certification by prominent VCs	1. The diversity of syndication relationships improves VCs' overall efficiency and efficiency in creating public companies from the portfolio companies 2. The frequency of syndicating investments improves VCs' overall efficiency and especially efficiency in completing deals 3. Uncertainty intensifies the impact of both frequency and diversity on firm efficiency	1. A central position in syndication networks improves VC firm performance 2. Prior position is a major determinant of future position in VC syndication networks 3. VC firms in the most central positions tend to sustain their positions over time, creating high barriers to success for newcomer firms 4. Changes in the number of general partners contribute to changes in existing network positions

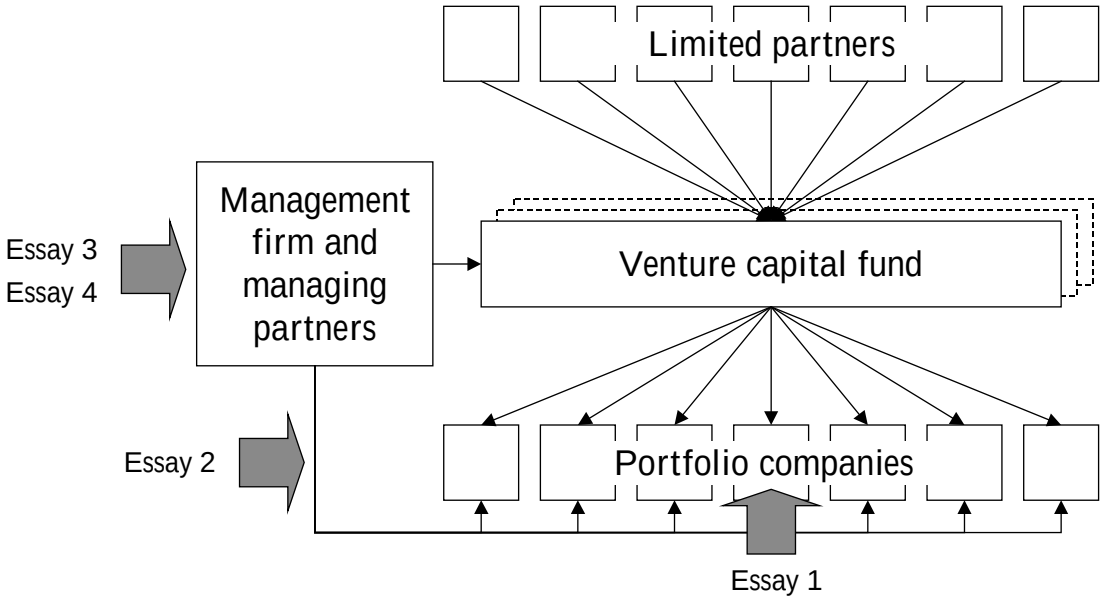

Figure 1 Positioning of the essays in the venture capital industry

REFERENCES

Admati AR, Pfleider P. 1994. Robust financial contracting and the role of venture capitalists. *Journal of Finance* 49(2): 371 – 402.

Aggarwal R. 1991. Justifying Investments in Flexible Manufacturing Technology. *Managerial Finance* 17: 77 – 88.

Ahuja G. 2000. The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal* 21: 317 – 343.

Akerlof, G. 1970. The Market for Lemons: Quality Uncertainty and the Market Mechanism. *Quarterly Journal of Economics* 84(3): 488 – 500.

Amit R, Brander J, Zott C. 1998. Why Do Venture Capital Firms Exist? Theory and Canadian Evidence. *Journal of Business Venturing* 13:441 – 466.

Anand B, Piskorski MJ. 2001. *Money can't buy my love: Financial resources and network positions in the formation of venture capitalist syndicates*. Working paper, Harvard Business School.

Baker M, Gompers PA. 2000. *The Determinants of Board Structure and Function at the Initial Public Offering.* Working paper, Harvard Business School.

Baker WE. 1984. The Social Structure of a National Securities Market. *American Journal of Sociology* 89: 775 – 811.

Baker WE. 1990. Market Networks and Corporate Behavior. *American Journal of Sociology* 96: 589 – 625.

Baldwin CY. 1982. Optimal Sequential Investment When Capital is not Readily Reversible. *Journal of Finance* 37: 763 – 782.

Baldwin C, Ruback R. 1986. Inflation, Uncertainty, and Investment. *Journal of Finance* 41: 657 – 699.

Barney J. 1991. Firm resources and sustained competitive advantage. *Journal of Management* 17: 99 – 120.

Barney JB, Busenitz L, Fiet JO, Moesel D. 1996. New Venture Teams' Assessment of Learning Assistance from Venture Capital Firms. *Journal of Business Venturing* 11(4): 257-272.

Barry CB. 1994. New Directions in Research on Venture Capital Finance. *Financial Management* 23(3): 3 – 15.

Barry CB, Muscarella CJ, Peavy JW, Vetsuypens MR. 1990. The Role of Venture Capital in the Creation of Public Companies. *Journal of Financial Economics* 27(2): 447 – 471.

Baum JAC, Calabrese T, Silverman B. 2000. Don't go it alone: Alliance network composition and startup's performance in Canadian biotechnology. *Strategic Management Journal* special issue 21(3): 267 – 294.

Beatty RP, Ritter JR. 1986. Investment Banking, Reputation, and the Underpricing of Initial Public Offerings. *Journal of Financial Economics* 15: 213 – 232.

Bergemann D, Hege U. 1998. Venture capital financing, moral hazard, and learning. *Journal of Banking and Finance* 22: 703 – 735.

Berger PG, Ofek E, Swary I. 1996. Investor Valuation of the Abandonment Option. *Journal of Financial Economics* 42: 257 – 287.

Berk J, Green R, Naik V. 1999. Optimal Investment, Growth Options, and Security Returns. *Journal of Finance* 54: 1553 – 1608.

Bernanke BS. 1983. Irreversibility, Uncertainty, and Cyclical Investment. *Quarterly Journal of Economics* 98: 85 – 106.

Black BS, Gilson RJ. 1998. Venture capital and the structure of capital markets: Banks versus stock markets. *Journal of Financial Economics* 47: 243 – 277.

Black F, Scholes M. 1973. The Pricing of Options and Corporate Liabilities. *Journal of Political Economy* 81: 637 – 654.

Bonacich P. 1987. Power and Centrality: A family of measures. *American Journal of Sociology* 92: 1170 – 1182.

Bonini C. 1977. Capital Investment under Uncertainty with Abandonment Options. *Journal of Finance and Quantitative Analysis*. March: 39 – 54.

Boocock G, Woods M. 1997. The Evaluation Criteria used by Venture Capitalists: Evidence from a UK Venture Fund. *International Small Business Journal* 16(1): 36 – 57.

Booth J, Smith R. 1986. Capital Raising, Underwriting, and the Certification Hypothesis. *Journal of Financial Economics* 15(1/2): 261 – 281.

Bowden RJ. 1994. Bargaining, Size, and Return in Venture Capital Funds. *Journal of Business Venturing* 9:307 – 330.

Brander J, Amit R, Antweiler W. 1999. *Venture Capital Syndication: Improved Venture Selection versus the Value-Added Hypothesis.* Working paper, University of British Columbia.

Brav A, Gompers PA. 1997. Myth or Reality? The Long-Run Underperformance of Initial Public Offerings: Evidence from Venture and Nonventure Capital-Backed Companies. *Journal of Finance* 52: 1791 – 1821.

Brealey S, Myers R. 1991. Principles of Corporate Finance. 4th edition. McGraw-Hill: New York, NY.

Brennan MJ, Schwartz ES. 1985. Evaluating Natural Resource Investments. *Journal of Business* 58: 135 – 158.

Brennan MJ, Trigeorgis L. 2000. Eds. *Project Flexibility, Agency, and Competition: New Developments in the Theory and Application of Real Options.* Oxford University Press: New York, NY.

Brophy DJ, Guthner MW. 1988. Publicly Traded Venture Capital Funds: Implications for Institutional "Fund of Funds" Investors. *Journal of Business Venturing* 3: 187 – 206.

Bruno AV, Tyebjee TT. 1985. The entrepreneur's search for capital. *Journal of Business Venturing* 1(1): 61–74.

Bygrave WD. 1987. Syndicated Investments by Venture Capital Firms: A Networking Perspective. *Journal of Business Venturing* 2(2): 139 – 154.

Bygrave WD. 1988. The Structure of the Investment Networks of Venture Capital Firms. *Journal of Business Venturing* 3: 137 – 158.

Bygrave WD. 1989. Early Rates of Return of 131 Venture Capital Funds Started 1978-1984. *Journal of Business Venturing* 4: 93 – 105.

Bygrave WD, Timmons JA. 1992. *Venture Capital at the Crossroads*. Harvard Business School Press: Boston, MA.

Bygrave WD, Hay M, Peeters JB. 1999. *The Venture Capital Handbook*. Pearson Education Limited: Harlow.

Campbell TS, Kracaw WA. 1980. Information Production, Market Signalling, and the Theory of Financial Intermediation. *Journal of Finance* 35(4): 863 – 882.

Carr P. 1988. The Valuation of Sequential Investment Opportunities. *Journal of Finance* 43: 1235 – 1256.

Carter RB, Manaster S. 1990. Initial Public Offerings and Underwriter Reputation. *Journal of Finance* 45(4): 1045 – 1067.

Carter RB, Dark FH, Singh A. 1998. Underwriter Reputation, Initial Returns, and the Long-Run Performance of IPO Stocks. *Journal of Finance* 53(1): 285 – 311.

Chan Y-S. 1983. On the Positive Role of Financial Intermediation in the Allocation of Venture Capital in a Market with Imperfect Information. *Journal of Finance* 38(5): 1543 – 1568.

Chemmanur TJ, Fulghieri P. 1994. Investment Bank Reputation, Information Production, and Financial Intermediation. *Journal of Finance* 49(1): 57 – 79.

Chiampou GF, Kallett JJ. 1989. Risk/Return Profile of Venture Capital. *Journal of Business Venturing* 4: 1 – 10.

Childs PD, Riddiough TJ, Triantis AJ. 1998. Capital Budgeting for Interrelated Projects: A Real Options Approach. *Journal of Financial and Quantitative Analysis* 33(3): 305 – 334.

Chua JH, Woodward RS. 1993. Splitting the Firm between the Entrepreneur and the Venture Capitalist with the Help of Stock Options. *Journal of Business Venturing* 8: 43 – 58.

Chung KH, Charoenwong C. 1991. Investment Options, Assets in Place, and the Risk of Stocks. *Financial Management* 20: 21 – 33.

Cochrane J. 2001. *The Risk and Return of Venture Capital*. Working paper, University of Chicago.

Cook KS, Emerson RM. 1978. Power, Equity and Commitment in Exchange Networks. American Sociological Review 43(October): 721 – 739.

Das TK, Teng B-S. 2000. A Resource-Based Theory of Strategic Alliances. *Journal of Management* 26(1): 31 – 61.

Dean BV, Giglierano JJ. 1990. Multistage Financing of Technical Start-Up Companies in Silicon Valley. *Journal of Business Venturing* 5: 375 – 389.

Dierickx I, Cool K. 1989. Asset stock accumulation and sustainability of competitive advantage. *Management Science* 35: 1504 – 1511.

Dixit AK, Pindyck RS. 1994. *Investment under Uncertainty*. Princeton University Press: Princeton, NJ.

Eisenhardt KM, Schoonhoven CB. 1996. Resource-Based View of Strategic Alliance Formation: Strategic and Social Effects in Entrepreneurial Firms. *Organization Science* 7(2): 136 – 150.

Elango B, Fried VH, Hisrich RD, Polonchek A. 1995. How Venture Capital Firms Differ. *Journal of Business Venturing* 10: 157 – 179.

Fenn GW, Liang N. 1998. New resources and new ideas: Private equity for small business. *Journal of Banking and Finance* 22: 1077 – 1084.

Fiet O. 1995. Risk Avoidance Strategies in Venture Capital Markets. *Journal of Management Studies* 32: 551 – 574.

Florida R, Kenney M. 1988. Venture Capital and High Technology Entrepreneurship. *Journal of Business Venturing* 3: 301 – 319.

Freear J, Wetzel WE. 1990. Who Bankrolls High-Tech Entrepreneurs? *Journal of Business Venturing* 5: 77 – 89.

Fried VH, Hisrich RD. 1994. Toward a model of Venture Capital Investment Decision Making. *Financial Management* 23(3): 28 – 37.

Gale I, Stiglitz J. 1989. The informational content of initial public offerings. *Journal of Finance* 44: 469 – 477.

Gifford S. 1997. Limited attention and the role of the venture capitalist. *Journal of Business Venturing* 12: 459 – 482.

Gompers PA. 1995. Optimal Investment, Monitoring, and the Staging of Venture Capital. *Journal of Finance* 50(5): 1461 – 1489.

Gompers PA. 1996. Grandstanding in the Venture Capital Industry. *Journal of Financial Economics* 42(1): 133 – 156.

Gompers PA, Lerner J. 1996. The Use of Covenants: An Analysis of Venture Partnership Agreements. *Journal of Law and Economics* 39: 463 – 498.

Gompers PA, Lerner J. 1998. Venture Capital Distributions: Short and Long-Run Reactions. *Journal of Finance* 53: 2161 – 2183.

Gompers PA, Lerner J. 1999a. An analysis of compensation in the U.S. venture capital partnership. *Journal of Financial Economics* 51(January): 3 – 44.

Gompers PA, Lerner J. 1999b. *The Venture Capital Cycle.* The MIT Press: Cambridge, MA.

Gompers PA, Lerner J. 1999c. *The Determinants of Corporate Venture Capital Successes: Organizational Structure, Incentives, and Complementarities*. NBER Working Paper No. W6725.

Gompers PA, Lerner J. 1999d. Conflict of Interest in the Issuance of Public Securities: Evidence from Venture Capital. *Journal of Law and Economics* 52: 1 – 28.

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

Gompers PA, Lerner J. 2001. *The Money of Invention: How Venture Capital Creates New Wealth.* Harvard Business School Press: Boston, MA.

Gorman M, Sahlman WA. 1989. What Do Venture Capitalists Do? *Journal of Business Venturing* 4(4): 231 – 248.

Granger CWJ. 1969. Investigating Causal Relations by Econometric Methods and Cross-Spectral Methods. *Econometrica* 34: 424 – 438.

Granovetter M. 1985. Economic action and social structure: A theory of embeddedness. *American Journal of Sociology* 91: 481 – 510.

Grant RM. 1996 Toward a knowledge-based theory of the firm. *Strategic Management Journal* 17: 109 – 122.

Grinblatt M, Hwang CY. 1989. Signalling and the pricing of new issues. *Journal of Finance* 44: 383 – 420.

Gulati R. 1995. Social structure and alliance formation patterns: A longitudinal analysis. *Administrative Science Quarterly* 40(4): 619 – 652.

Gulati R. 1998. Alliances and Networks. *Strategic Management Journal* 19: 293 – 317.

Gulati R. 1999. Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal* 20: 397 – 420.

Gulati R, Gargiulo M. 1999. Where Do Interorganizational Networks Come From? *American Journal of Sociology* 104(5): 1439 – 1493.

Hall J, Hofer CW. 1993. Venture Capitalists' Decision Criteria in New Venture Evaluation. *Journal of Business Venturing* 8: 25 – 42.

Hathaway N. 1990. Partial Takeovers as Put Options. *Accounting and Finance*. May: 27 – 38.

Hellmann T. 1998. The Allocation of Control Rights in Venture Capital Contracts. *Rand Journal of Economics* 29: 57 – 76.

Hellmann T, Puri M. 2000. The Interaction between Product Market and Financing Strategy: The Role of Venture Capital. *Review of Financial Studies* 13(4): 959 – 984.

Hellmann T, Puri M. 2002. Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence. *Journal of Finance* 57(1): 169 – 197.

Howe KM, McCabe GM. 1983. On Optimal Asset Abandonment and Replacement. *Journal of Finance and Quantitative Analysis* 18: 295 – 305.

Huntsman B, Hoban JP. 1980. Investments in new enterprise: Some empirical observations on risk return, and market structure. *Financial Management* 9: 44 – 51.

Ikenberry D, Vermaelen T. 1996. The Option to Repurchase Stock. *Financial Management* 25: 9 – 24.

Ingersoll JE, Ross SA. 1992. Waiting to Invest: Investment and Uncertainty. *Journal of Business* 65(January): 1 – 29.

Jain BA, Kini O. 2000. Does the presence of venture capitalists improve the survival profile of IPO firms? *Journal of Business Finance and Accounting* 27(9/10): 1139 – 1176.

Jensen MC, WH. Meckling. 1976. Theory of the Firm: Managerial Behavior, Agency Costs and Ownership Structure. *Journal of Financial Economics* 3(4): 305 – 360.

Johnson JM, Miller RE. 1988. Investment Banker Prestige and the Underpricing of Initial Public Offerings. *Financial Management* 17: 19 – 29.

Kemna AGZ. 1993. Case Studies on Real Options. *Financial Management* 22: 259 – 270.

Kirilenko AA. 2001. Valuation and Control in Venture Finance. *Journal of Finance* 56(2): 565 – 587.

Klein B, Leffler KB. 1981. The Role of Market Forces in Assuring Contractual Performance. *Journal of Political Economy* 89(4): 615 – 641.

Kogut B. 1991. Joint Ventures and the Option to Expand and Acquire. *Management Science* 37: 19 – 33.

Kortum S, Lerner J. 2000. Assessing the Contribution of Venture Capital to Innovation. *RAND Journal of Economics* 31(4): 674 – 692.

Kulatilaka N. 1995. The Value of Flexibility: A General Model of Real Options. Pages 89 – 107 in *Real Options in Capital Investment*. Edited by Lenos Trigeorgis. Praeger: New York, NY.

Laamanen T. 1999. Option Nature of Company Acquisitions Motivated by Competence Acquisition. *Small Business Economics* 12: 149 – 168.

Lander DM, Pinches GE. 1998. Challenges to the Practical Implementation of Modelling and Valuing Real Options. *Quarterly Review of Economics and Finance* 38: 537 – 567.

Lee CJ. 1988. Capital Budgeting under Uncertainty: The Issue of Optimal Timing. *Journal of Business Finance and Accounting* 15(Summer): 155 – 168.

Lee MH. 1997. Valuing Finite Maturity Investment-Timing Options. *Financial Management* 26(Summer): 58 – 66.

Leland HE, Pyle DH. 1977. Informational Asymmetries, Financial Structure, and Financial Intermediation. *Journal of Finance* 32(2): 371 – 387. Papers and proceedings of the thirty-fifth annual meeting of the American Finance Association, Atlantic City, New Jersey.

Lerner J. 1994a. Venture capitalists and the decision to go public. *Journal of Financial Economics* 35(June): 293 – 316.

Lerner J. 1994b. The Syndication of Venture Capital Investments. *Financial Management* 23(3): 16 – 27.

Lerner J. 1995. Venture Capitalists and the Oversight of Private Firms. *Journal of Finance* 50(1): 301 – 318.

Lin TH, Smith RL. 1998. Insider reputation and selling decisions: the unwindling of venture capital investments during equity IPOs. *Journal of Corporate Finance* 4: 241 – 263.

Lockett A, Wright M. 2001. The syndication of venture capital investments. *Omega* 29: 375 – 390.

MacMillan IC, Kulow DM, Khoylian R. 1988. Venture Capitalists' Involvement in Their Investments: Extent and Performance. *Journal of Business Venturing* 4(1): 27 – 47.

MacMillan IC, Siegel R, Subbanarasimha PN. 1985. Criteria Used by Venture Capitalists to Evaluate New Venture Proposals. *Journal of Business Venturing* 1: 119 – 128.

MacMillan IC, Zemann L, Subbanarasimha PN. 1987. Criteria Distinguishing Successful from Unsuccessful Ventures in the Venture Screening Process. *Journal of Business Venturing* 2: 123 – 187.

Majd S, Pindyck R. 1987. Time to build, option value and investment decisions. *Journal of Financial Economics* 18(1): 7 – 27.

Manigart S. 1994. The founding rate of venture capital firms in three European countries (1970-1990). *Journal of Business Venturing* 9(6): 525 – 541.

Manigart S, Waele K, Wright M, Robbie K, Desbrières P, Sapienza HJ, Beekman A. 2002. Determinants of required return in venture capital investments: A five-country study. *Journal of Business Venturing* 17: 291 – 312.

Margrabe W. 1978. The Value of an Option to Exchange One Asset for Another. *Journal of Finance* 33: 177 – 186.

Mauer DC, Triantis AJ. 1994. Interactions of Corporate Financing and Investment Decisions: A Dynamic Framework. *Journal of Finance* 49: 1253 – 1277.

Maula MVJ. 2001. *Corporate venture capital and the value-added for technology-based new firms.* Doctoral dissertation, Institute of Strategy and International Business, Helsinki University of Technology.

Maula MVJ, Murray G. 2001. Corporate venture capital and the creation of US public companies: The impact of sources of venture capital on the performance of portfolio companies. In *Creating Value: Winners in the New Business Environment*. Hitt MA, Amit R, Lucier C, Nixon RD (eds). Blackwell Publishers: Oxford, UK.

McDonald RL, Siegel DR. 1985. Investment and the Valuation of Firms When There Is an Option to Shut Down. *International Economic Review* 26(2): 331 – 349.

McDonald RL, Siegel DR. 1986. The Value of Waiting to Invest. *Quarterly Journal of Economics* 101(November): 707 – 727.

McGrath RG. 1997. A Real Options Logic for Initiating Technology Positioning Investments. *Academy of Management Review* 22. October: 974 – 996.

Megginson WL, Weiss KA. 1991. Venture Capitalist Certification in Initial Public Offerings. *Journal of Finance* 46(3): 879 – 903.

Merton RK. 1968. The Matthew effect in science. *Science* 159: 56 – 63.

Morck R, Schwartz E, Stangeland D. 1989. The Valuation of Forestry Resources under Stochastic Prices and Inventories. *Journal of Financial and Quantitative Analysis* 24: 473 – 487.

Morris PA, Teisberg EO, Kolbe AL. 1991. When Choosing R&D Projects, Go with Long Shots. *Research-Technology Management* 34: 35 – 40.

Muzyka D, Birley S, Leleux B. 1996. Trade-offs in the investment decisions of European Venture Capitalists. *Journal of Business Venturing* 11: 273 – 287.

Myers SC. 1977. Determinants of Corporate Borrowing. *Journal of Financial Economics* 5: 147 – 175.

Myers SC, Majluf NS. 1984. Corporate financing and investment decisions when firms have information that investors do not have. *Journal of Financial Economics* 13: 187 – 221.

Newton DP, Pearson AW. 1994. Application of Option Pricing Theory to R&D. *R&D Management* 24: 83 – 89.

Norton E, Tenenbaum BH. 1993. Specialization versus Diversification as a Venture Capital Investment Strategy. *Journal of Business Venturing* 8: 431 – 442.

NVCA. 2002. The Venture Capital Industry: An Overview. Online document, URL: http://www.nvca.org/def.html, Referred 2002-15-01.

Paddock J, Siegel D, Smith J. 1988. Option Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases. *Quarterly Journal of Economics* 103: 479 – 508.

Penrose E. 1959. *The Theory of the Growth of the Firm*. Oxford University Press: New York, NY.

Pindyck RS. 1988. Irreversible Investment, Capacity Choice, and the Value of the Firm. *The American Economic Review* 78: 969 – 985.

Pindyck RS. 1991. Irreversibility, Uncertainty, and Investment. *Journal of Economic Literature* 26: 1110 – 1148.

Podolny JM. 1993. A Status-Based Model of Market Competition. *American Journal of Sociology* 98: 829 – 872.

Podolny JM. 1994. Market Uncertainty and the Social Character of Economic Exchange. *Administrative Science Quarterly* 39: 458 – 483.

Podolny JM. 2001. Networks as Pipes and Prisms of the Market. *American Journal of Sociology* 107(1): 33 – 60.

Podolny J, Feldman A. 1997. *Is It Better to Have Status or to Know What You Are Doing? An Examination of Position Capability in Venture Capital Markets*. Stanford University: Research paper no. 1455.

Quigg L. 1993. Empirical Testing of Real Option-Pricing Models. *Journal of Finance* 48: 265 – 296.

Quigg L. 1995. Optimal Land Development. Pages 265 – 280 in *Real Options in Capital Investment*. Edited by Lenos Trigeorgis. Praeger: New York, NY.

Rah J, Jung K, Lee J. 1994. Validation of the Venture Evaluation Model in Korea. *Journal of Business Venturing* 9: 509 – 524.

Rea RH. 1989. Factors Affecting Success and Failure of Seed Capital/Start-Up Negotiations. *Journal of Business Venturing* 4: 149 – 158.

Rosenstein J. 1988. The board and strategy: Venture capital and high technology. *Journal of Business Venturing* 3: 159 – 170.

Rosenstein JA, Bruno V, Bygrave WD, Taylor NT. 1993. The CEO, Venture Capitalists, and the Board. *Journal of Business Venturing* 8(2): 99 – 113.

Rosman AJ, O'Neill HM. 1993. Comparing the Information Acquisition Strategies of Venture Capital and Commercial Lenders: A Computer-Based Experiment. *Journal of Business Venturing* 8: 443 – 460.

Ruhnka JC, Young JE. 1987. A Venture Capital Model of the Development Process for New Ventures. *Journal of Business Venturing* 2: 167 – 184.

Ruhnka JC, Young JE. 1991. Some Hypotheses about Risk in Venture Capital Investing. *Journal of Business Venturing* 6(2): 115 – 133.

Ruhnka JC, Feldman HD, Dean TJ. 1992. The "Living Dead" Phenomenon in Venture Capital Investments. *Journal of Business Venturing* 7: 137 – 155.

Rumelt RP. 1984. Toward a strategic theory of the firm. Pages 557 – 570 in Lamb RB. Ed. *Competitive Strategic Management.* Prentice-Hall: Englewood Cliffs, NJ.

Sahlman WA. 1990. The Structure and Governance of Venture-Capital Organizations. *Journal of Financial Economics* 27: 473 – 521.

Sahlman WA. 1993. Aspects of Financial Contracting in Venture Capital. Pages 229 – 242 in Chew DH. Ed. *The New Corporate Finance: Where Theory Meets Practice.* McGraw-Hill, New York, NY.

Sapienza HJ. 1992. When Do Venture Capitalists Add Value? *Journal of Business Venturing* 7(1): 9 – 27.

Sapienza HJ, Gupta AK. 1994. Impact of agency risks and task uncertainty on venture capitalist – CEO interaction. *Academy of Management Journal* 37(6): 1618 – 1632.

Sapienza H, Korsgaard MA. 1996. Managing investor relations: The impact of procedural justice in establishing and sustaining investor support. *Academy of Management Journal* 39: 544 – 574.

Sapienza HJ, Manigart S, Vermeir W. 1996. Venture Capitalist Governance and Value Added in Four Countries. *Journal of Business Venturing* 11(6): 439 – 469.

Seppä TJ, Laamanen T. 2001. Valuation of Venture Capital Investments: Empirical Evidence. *R&D Management* 31(2): 215 – 230.

Shane S, Cable D. 2002. Network Ties, Reputation, and the Financing of New Ventures. *Management Science* 48(3): 364 – 381.

Shepherd DA. 1999. Venture Capitalists' Assessment of New Venture Survival. *Management Science* 45(5): 621 – 632.

Siskos J, Zopounidis C. 1987. The evaluation criteria of the venture capital investment activity: An interactive assessment. *European Journal of Operational Research* 31: 304 – 313.

Smit HTJ. 1997. Investment Analysis of Offshore Concessions in The Netherlands. *Financial Management* 26: 5 – 17.

Smith KW, Triantis A. 1995. The Value of Options in Strategic Acquisitions. Pages 135 – 149 in Trigeorgis L. Ed. *Real Options in Capital Investment*. Praeger: New York, NY.

Sorenson O, Stuart T. 2001. Syndication Networks and the Spatial Distribution of Venture Capital Investments. *American Journal of Sociology* 106(6): 1546 – 1588.

Spence AM. 1973. Job Market Signaling. *Quarterly Journal of Economics* 87(3): 355 – 374.

Spence AM. 1974. *Market Signaling: Informational Transfer in Hiring and Related Screening Processes*. Harvard University Press: Cambridge, MA.

Steier L, Greenwood R. 1995. Venture Capitalist Relationships in the Deal Structuring and Post-Investment Stages of New Firm Creation. *Journal of Management Studies* 32(3): 337 – 357.

Stuart TE. 1998. Network positions and propensities to collaborate: An investigation of strategic alliance formation in a high-technology industry. *Administrative Science Quarterly* 43(3): 668 – 698.

Stuart TE, Hoang H, Hybels R. 1999. Interorganizational Endorsements and the Performance of Entrepreneurial Ventures. *Administrative Science Quarterly* 44(2): 315 – 349.

Stulz R. 1982. Options on the Minimum or the Maximum of Two Risky Assets: Analysis and Applications. *Journal of Financial Economics* 10: 161 – 185.

Stulz R, Johnson H. 1985. An Analysis of Secured Debt. *Journal of Financial Economics*. July: 161 – 185.

Teisberg EO. 1993. Capital Investment Strategies under Regulation. *RAND Journal of Economics* 24: 591 – 604.

Timmons JA, Bygrave WD. 1986. Venture Capital's Role in Financing Innovation for Economic Growth. *Journal of Business Venturing* 1: 161 – 176.

Titman S. 1985. Urban Land Prices under Uncertainty. *American Economic Review*. June: 505 – 514.

Tourinho O. 1979. *The Option Value of Reserves of Natural Resources*. Working paper, University of California at Berkeley.

Trester JJ. 1998. Venture capital contracting under asymmetric information. *Journal of Banking and Finance* 22: 675 – 699.

Trigeorgis L. 1991. A Log-Transformed Binomial Numerical Analysis Method for Valuing Complex Multi-Option Investments. *Journal of Financial and Quantitative Analysis* 26: 309 – 326.

Trigeorgis L. 1993a. The Nature of Option Interactions and the Valuation of Investments with Multiple Real Options. *Journal of Financial and Quantitative Analysis* 28: 1 – 20.

Trigeorgis L. 1993b. Real Options and Interactions with Financial Flexibility. *Financial Management* 22: 202 – 224.

Trigeorgis L. 1995. Ed. Real Options in Capital Investment. Praeger: New York, NY.

Trigeorgis L. 1996. *Real Options: Managerial Flexibility and Strategy in Resource Allocation.* The MIT Press: Cambridge, MA.

Tyebjee TT, Bruno AV. 1984. A Model of Venture Capital Investment Activity. *Management Science* 30(9): 1051 – 1065.

Welch I. 1989. Seasoned offerings, imitation costs, and the underpricing of initial public offerings. *Journal of Finance* 44: 421 – 449.

Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* 5(2): 171 – 180.

White HC. 1981. Where do markets come from? *American Journal of Sociology* 87: 517 – 547.

Williams JT. 1993. Equilibrium and Options on Real Assets. *The Review of Financial Studies* 6(4): 825 – 850.

Willner R. 1995. Valuing Start-Up Venture Growth Options. Pages 221 – 239 in Trigeorgis L. Ed. Real Options in Capital Investment. Praeger: Westport.

Wilson R. 1968. The theory of syndicates. *Econometrica* 36(1): 119 – 132.

Wright M, Robbie K. 1998. Venture Capital and Private Equity: A Review and Synthesis. *Journal of Business Finance & Accounting* 25: 521 – 570.

Zacharakis AL, Meyer GD. 1998. A Lack of Insight: Do Venture Capitalists Really Understand Their Own Decision Process? *Journal of Business Venturing* 13: 57 – 76.

Zacharakis AL, Meyer GD. 2000. The Potential of Actuarial Decision Models: Can They Improve the Venture Capital Investment Decision? *Journal of Business Venturing* 15: 323 – 346.

ESSAY 1:

VALUATION OF VENTURE CAPITAL INVESTMENTS:

EMPIRICAL EVIDENCE

Abstract

This paper constructs a simple binomial valuation model in modelling the risk-return profiles of venture capital investments, and tests the model using the valuation data of 421 U.S. venture capital transactions and 176 initial public offerings. It is found that the model is consistent with the previous knowledge on the risk-return profile of venture capital investments. The results also confirm the hypotheses that early-stage ventures have higher implied risk and implied volatility of returns than more established ones.

Additionally, the paper analyses the predictive power of the binomial pricing model, and compares it to corresponding 'traditional' models that utilise risk-adjusted rates of return. We construct one-step ex post return forecasts for the sample ventures, and compare the results with actual realised returns. The findings indicate that the fit of the binomial model is better than the fit of the corresponding 'traditional' models.

The results imply that option-based methods have empirical relevance in the analysis of the risk-return structure of privately held companies and projects. However, the results demonstrate that the valuations of venture capital backed companies often result in extreme outcomes that are difficult to capture with any ex ante pricing model.

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1 INTRODUCTION

Consider a firm that has a unique business concept, significant growth opportunities, and no real positive cash flow to show the profit potential of the venture. Valuing such high-growth, high-uncertainty firms is a major challenge faced by most venture capital firms. A typical venture capital valuation procedure involves an analysis of potential future cash flows, an analysis of comparative firms' stock prices or IPO performance, and an analysis of the price-to-earnings ratio or the price-to-sales ratio of the venture. Yet, the resulting valuations of these growth firms seem to defy all the common wisdom on growth firm valuation.

The option value of uncertainty has been studied extensively in the research on investments for two decades (e.g. Dixit and Pindyck, 1994; Trigeorgis, 1996; Brennan and Trigeorgis, 2000). Even the uncertainty inherent in venture capital investments has been conceptually shown to be decomposable into a set of options. Sahlman (1993) identifies three major options inherent in venture capital investments: the option to abandon investment, the option to re-value a project, and the option to increase capital commitment. In general, the theory of investment has made significant advances, and already enables elaborate analyses of real options and option interactions. Yet, the lack of empirical evidence regarding the practical applicability of option-based pricing models would seem effectively to inhibit adoption in practice.

This paper sets out to test a binomial option-based valuation model with a large sample of venture capital investments. The results contribute both to theory and to practice in at least two ways. Firstly, despite the wide variety of option-pricing applications, there have been no empirical tests of the applicability of option-based pricing models in venture capital investment decision making. Secondly, real option valuation, in general, has been tested empirically in only a few published papers, including those of Paddock *et al.* (1988), Quigg (1993), Berger, Ofek, and Swary (1996), and Moel and Tufano (1998). More empirical evidence is clearly needed to further validate the applicability of option-based valuation methods to real investment opportunities in general.

This paper contributes to existing venture capital valuation methodologies by providing the first empirical study in which the applicability of an option-based valuation methodology is tested. Using the ex post valuation data from 421 U.S. venture capital transactions and 176 initial public offerings, it is possible to test a binomial valuation model in modelling the risk-return profiles of venture capital investments. Knowing the ex post values of the target firm at each stage of the venture capital investment process enables us to determine the implicit risk-neutral probabilities that the venture capitalists would need to determine to correctly price the investments. Similar risk-return profiles of venture capital investments have been examined previously in surveys and small-

sample studies, but there are no previous established structures or structured approaches for analysing the risk-return profiles of venture capital investments.

The rest of the paper is organised as follows. The next section develops the binomial valuation model for venture capital investments and the testable hypotheses on the consistency of the model. The third section describes the data and methodology used in the empirical testing of the model. The fourth section examines the consistency of the model empirically. The fifth section analyses the ex post predictive power of the model by comparing estimated to realised returns. Finally, conclusions are presented in section six.

2 HYPOTHESIS DEVELOPMENT

2.1 Previous research

The valuation of venture capital backed companies is difficult, since the shares of these companies are unquoted and illiquid, and the uncertainty associated with these investments is high before the investors reach an exit[2] (Wright and Robbie, 1998). Option-based methods have been suggested as one possible improvement to the existing techniques. Utilising option-pricing theory, Willner (1995) made one of the few attempts to model the value of a start-up firm. He pointed out that many start-ups have the characteristics of growth options, but that traditional option methodology is incompetent in valuing them. Willner (1995) criticised the assumption of a continuous cash flow generation process behind the traditional option methodology, and presented a jump model for the pricing of start-up companies. However, Willner's (1995) assumption of a simple exponential growth process with upward jumps may be considered somewhat restrictive. Additionally, there is little empirical evidence regarding the performance of the model in practice.

Jägle (1999) suggested that sequential new product development processes could be modelled with a binomial tree and utilising a simple option-based pricing methodology. Using a pharmaceutical R&D project as an example, he argued that the decisions derived from a corresponding traditional discounted cash flow (DCF) model may differ significantly from decisions derived from the theoretically more sound option-based model. Jägle (1999) further argued that the traditional DCF approach is problematic, since one cannot observe the correct discount rate for each phase of the R&D project. Thus, traditional DCF techniques may fail to value correctly future cash flows that are conditional on the success of the previous stages of product development.

The life-cycle of venture capital backed companies is frequently modelled as a sequential series of stages (e.g., Plummer, 1987). Companies are seen to advance

[2] 'Exit' refers to the realisation of investments in a public offering or a private trade sale.

gradually from the seed stage to the start-up stage, then to the first stage, to the second stage, and so on, to finally reach the exit stage. At the exit stage, the shares of the company become liquid in a public offering or a trade sale. However, many companies never reach the exit stage because of a bankruptcy or the 'living dead' phenomenon (Ruhnka *et al*., 1992). 'Living dead' companies stay alive and progress modestly, but their shares remain illiquid and they are no longer able to raise additional venture capital financing.

The risk-return profile of such staged venture capital investments has been studied previously with survey and interview methods (Wetzel, 1981; Ruhnka and Young, 1987; Chiampou and Kallett, 1989; Ruhnka and Young, 1991). In addition, psychological risk theory has been applied to explain the profiles found (Ruhnka and Young, 1991). The existing research shows that the risk of loss associated with venture capital investment decreases steadily as the venture reaches later stages of development. Moreover, the venture capitalists' rate of return requirement has been found to decline in a similar fashion.

Because of the lack of data available, large-scale empirical studies on the returns and valuations of venture capital transactions did not appear until the mid-1990s. Earlier studies were based on much smaller samples. Bygrave and Timmons (1992) reported evidence of venture capital returns and transaction valuations from two surveys with samples of less than 100 each, whereas Houlihan Valuation Advisors (1998) examined the pricing of 1,247 private U.S. venture capital investments in ventures that went public between January 1993 and June 1997[3].

Bygrave and Timmons (1992) reported the results of Bygrave and Stein (1989) and Bygrave and Stein (1990). They found that the return on the venture capital investment at the IPO was 22.5 times for the first round, 10.0 times for the second round, and 3.7 times for the third round. The results imply diminishing risk as the venture reaches later stages of development.

In a similar fashion, Houlihan Valuation Advisors (1998) conclude that the sequential order of the financing round is a significant factor in determining the value increase from the previous round to the next. Later rounds are associated with higher valuations, even independent of the company's stage of development. Additionally, they found that the step-ups in value[4] decreased with the stage of development of the company's business and with increases in amounts raised in any particular round. Company location and industry type had also predictive power in company valuations. However, Houlihan Valuation Advisors (1998) did not find evidence regarding the time variation

[3] Houlihan Valuation Advisors used the VentureOne database to access the transaction data.

[4] Houlihan Valuation Advisors (1998) defined step-up in value as the increase in a company's pre-money valuation between two financing rounds, calculated as the pre-money valuation at a round divided by the pre-money valuation at a prior round.

of step-ups in value, as no specific years appeared significant in determining the differences of the step-ups in value.

2.2 Model structure

Motivated by Jägle's (1999) pricing model, we use a simple binomial valuation framework for analysing the valuation histories of the ventures in our sample. The model is based on the principles of risk-neutral option valuation originally put forward by Black and Scholes (1973) and later expanded by Cox, Ross, and Rubinstein (1979). Such a discrete-time binomial model is conceptually applicable to venture capital backed companies, since the value of these privately held companies is observable only at a few discrete points of time.

Consider first an asset, the current value of which is denoted as S, and construct a one-period binomial tree so that the asset's value can be either S^+ or S^- at the end of the period. Let the actual probabilities of these states be p and 1-p, accordingly.

The traditional present value framework suggests that the value of the asset, S, is equal to its probability weighted expected value at the end of the period, discounted by the risk-adjusted rate of return R. In other words, for period i of length t,

$$S_i = \frac{p_i S_i^+ + (1 - p_i) S_i^-}{(1 + R_i)^{t_i}}. \qquad (1)$$

Option-pricing techniques alleviate the need to use risk-adjusted rates of return by utilising risk-neutral pricing. If it is possible to set up a risk-free hedge portfolio of options and an exactly offsetting position in the underlying asset, the value of the hedge portfolio is unaffected by changes in the asset price. Thus, future positions can be discounted using the risk-free rate of return. The probabilities of the future states of the binomial model are in this case known as risk-neutral probabilities. The risk-neutral probability q is defined so that the value of S is, in an arbitrage-free world, equal to

$$S_i = \frac{q_i S_i^+ + (1 - q_i) S_i^-}{(1 + r_{f,i})^{t_i}} \qquad (2)$$

where we denote the risk-free rate of one period with r_f. Figure 1 illustrates the traditional one-step binomial tree and the corresponding risk-neutral tree.

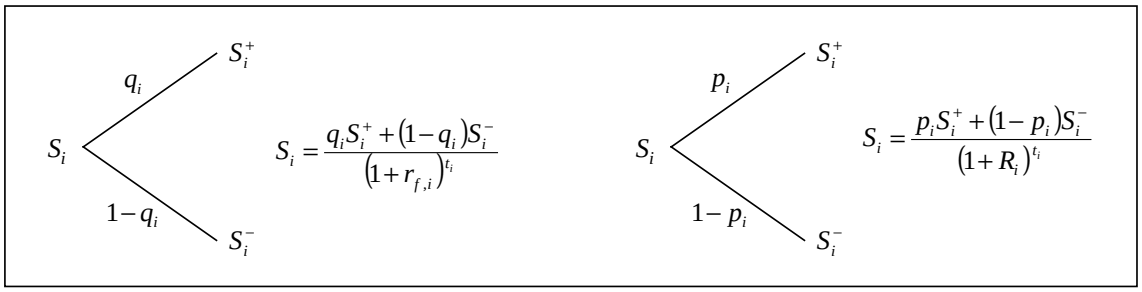


Figure 1 *Left side: One-period risk-neutral pricing model with risk-neutral success probabilities and a risk-free rate of return. Right side: One-period traditional pricing model with actual success probabilities and a risk-adjusted rate of return.*

We model each stage of a venture capital investment as a one-step binomial tree discussed above. Each stage has thus two outcomes: 'good' and 'bad'. We assume that the good outcome results in an increase in value by multiplier k ($k > 1$), and that the bad outcome results in a decrease in value by multiplier $1/k$. Each stage is followed by a similar one-step tree that represents the next stage. The final outcome is the value of the liquid shares of the venture at exit.

To establish the risk-neutral binomial model for venture capital investments, we define our notation as follows. For each stage i, the risk-neutral probability of success is q_i, the time length of the stage is t_i and the applicable risk-free discount rate for the stage is $r_{f\,i}$. The model will then result in the tree structure shown in Figure 2.

The reason to do the conversion to the risk-neutral world is that the traditional present value framework (1) is problematic in venture capital situations. The problem in applying this model to venture capital situations is that we must know the appropriate risk-adjusted rate of return for each stage, as Jägle (1999) points out in the case of sequential R&D projects. In addition, we should be able to separate between the risk included in the success probabilities and the risk included in the risk-adjusted rate of return. The capital asset pricing model suggests that the non-diversifiable or private part of risk should be reflected by the success probabilities, and the diversifiable or market-priced part of risk should be included in the risk-adjusted rate of return. However, Jägle (1999) argues that this view is incomplete because the amount of systematic risk varies every step, and because the commercial part of the private risk is not independent of economic conditions.

The risk-neutral framework should offer improvement to some of these problems. It is possible to use the risk-free rate of return throughout the analysis, and the unknown risk-neutral success probabilities are no more difficult to estimate from a data set than the actual success probabilities needed in the traditional framework.

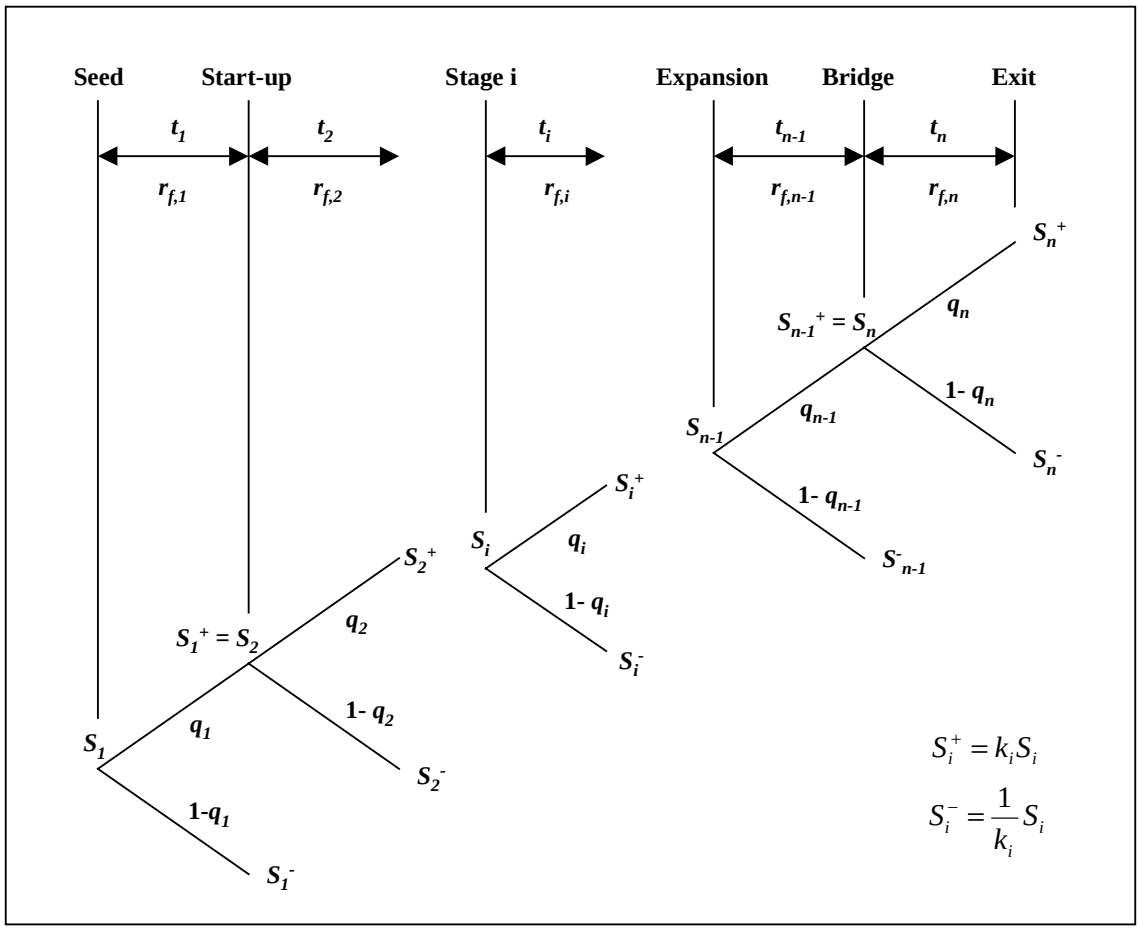


Figure 2 *Venture capital investments as risk-neutral success / failure binomial trees*

We now derive the necessary equations for applying our risk-neutral binomial valuation framework. From (2), we can solve the one-period risk-neutral probability *q* for stage *i* as follows:

$$q_i = \frac{S_i\left(1+r_{f,i}\right)^{t_i} - S_i^-}{S_i^+ - S_i^-} \tag{3}$$

We set $S_i^+ = k_i S_i$ and $S_i^- = 1/k_i \cdot S_i$ in (3), as suggested above, and require $k_i > 1 \quad \forall i$. The ratio of two consecutive venture valuations yields an estimate for k_i if the value of the venture increases and for $1/k_i$ if the value decreases. Thus, we obtain an estimate for q_i each period as follows:

$$q_i = \frac{\left(1+r_{f,i}\right)^{t_i} - \frac{1}{k_i}}{k_i - \frac{1}{k_i}} \qquad 0 < q_i \leq 1 \tag{4}$$

Let $r_{f,i} = 8\%$ and $t_i = 2$. When we now let *k* vary, we obtain a conventional risk-return trade-off plotted on the left side of Figure 3, in which the risk-neutral success

probabilities *q* act as a proxy for risk and *k* as a proxy for return in the good state of nature. The binomial pricing model assumes that larger returns should be associated with smaller risk-neutral success probabilities, and that the relationship between *q* and *k* is decreasing and convex.

If we accept that the upside return measure *k* is consistent with Black-Scholes option-pricing models, we can also establish a direct relationship between volatility (risk) and observed returns (*k*). According to Cox, Ross, and Rubinstein's (CRR) binomial tree models, implied volatility could then be calculated from return data as follows.

$$k_i = e^{\sigma_i \sqrt{t_i}}$$
$$\sigma_i = \frac{\ln k_i}{\sqrt{t_i}} \qquad (5)$$

This formula shows that the conventional CRR models assume that larger returns should be associated with larger implied volatility, and that the relationship between σ and *k* is increasing and convex. The right side of Figure 3 illustrates this risk-return trade-off when $t = 2$ years.

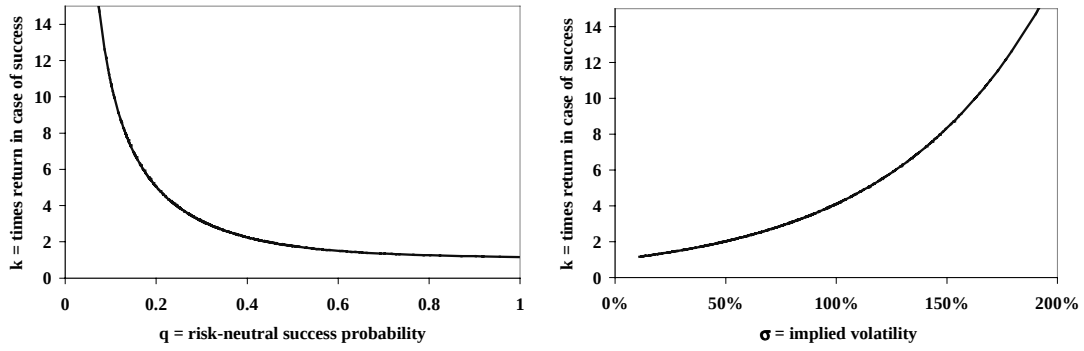


Figure 3 *Left side: The relationship between* k *(a proxy for return) and* q *(a proxy for risk) when* t *= 2 years and* r_f *= 8%. Right side: The relationship between* k *and Cox-Ross-Rubinstein implied volatility* σ *when* t *= 2 years.*

It is certainly difficult to believe that the assumptions of conventional CRR trees would hold in the case of venture capital backed private companies. Firstly, the assumption of asset prices following Geometric Brownian Motion is clearly problematic, as these companies often experience sudden progresses or failures that vastly affect the value of the venture. Jump processes offer somewhat improved possibilities to the pricing of this kind of assets (Merton, 1976; Willner, 1995). Secondly, venture capital assets are not traded continuously and the pricing process is not entirely competitive. Furthermore, value-related information is largely asymmetric and not easily available to investing parties. Despite these major shortcomings, it is still interesting to investigate how the Cox-Ross-Rubinstein type of implied volatility – a traditional proxy for risk – is actually

related to the value and fundamental characteristics of new ventures. A CRR approximation makes this possible, since we can calculate what the implied volatility would have been at each financing round of the venture. This increases our understanding on the implied risk of the ventures at different stages of development.

We finally note that each stage of development of the model in which venture capital financing occurs represents in effect an option to abandon the venture, as explained by Sahlman (1993). The venture capitalists will not invest if the venture's future does not look sufficiently bright. Not investing results in an early exit presumably at a low price, a bankruptcy of the venture, or the 'living dead' phenomenon in which the venture stays alive but experiences only modest progress and makes investors unable to realise their investments. Thus, each stage may result in abandonment and a modest or zero outcome for equity holders.

2.3 Hypotheses for model consistency

To demonstrate that the risk-neutral binomial valuation model is a reasonable and consistent framework for the valuation analysis of new ventures, we construct six testable hypotheses. We base the hypotheses on previous research on the risk-return profile of venture capital investments, which indicates that the risk of loss associated with these investments decreases as the venture reaches higher stages of development. Thus, the proxy for risk derived from the model should behave accordingly.

According to the survey of Ruhnka and Young (1987), venture capitalists expect that the risk of loss associated with venture capital investments decreases steadily as a venture reaches higher stages of development. Their results indicate that the aggregate risk of loss is as high as 66% for seed investments, and around 20% for bridge financings. Wetzel (1981) reports results in line with Ruhnka and Young (1987). Both report also that the venture capitalists' required rate of return declines as the venture reaches higher stages of development. Plummer (1987) supports this observation.

All these studies also indicate that it is more probable that a venture will fail in the early stages of development rather than in the later stages of development. There is considerably more uncertainty present in ventures that are in an early stage of development than in ventures that are about to make an initial public offering. Therefore, as the venture advances from the first stage of development to the second stage, the risk of loss decreases more than if the venture advances from stage four to stage five. Thus, we first hypothesise that the risk-neutral probability of reaching a subsequent financing round will be smaller for early-stage ventures than later-stage ventures. Similarly, the implied volatility of returns will be larger for early-stage ventures than later-stage ventures.

Hypothesis 1a: *The risk-neutral probabilities of the binomial model are smaller for ventures in early stages of development than for ventures in later stages of development.*

Hypothesis 1b: *Cox-Ross-Rubinstein implied volatility is larger for ventures in early stages of development than for ventures in later stages of development.*

In many cases, ventures do not follow the sequential order of the development stages. It is possible for a venture to develop rapidly and 'jump' over certain development stages to raise additional venture capital financing at a higher stage of development. For example, a start-up venture may be able to raise a large amount of financing and proceed to the bridge stage without additional financing rounds – and thus possibly without indications of company value. Similarly, it is possible that a venture experiences slow progress and raises two venture capital financing rounds at the same stage of development.

Consider now two observations of the valuation of the same venture that are not from consecutive stages of development. Let the first observation be from the start-up stage of development and the second one from the bridge financing stage. Consider then two similar observations that are from consecutive stages of development, perhaps from the seed stage and the start-up stage. In the first case, the aggregate risk of loss is reduced more than in the second case because the venture has advanced through more stages of development in the first case (Wetzel, 1981; Ruhnka and Young, 1987). This leads us to hypothesise that the risk-neutral success probabilities should be smaller for 'longer' steps and larger for 'shorter' steps. In other words:

Hypothesis 2a: *The risk-neutral probabilities of the binomial model are negatively related to the period between two financing rounds.*

The relationship between the Cox-Ross-Rubinstein type of implied volatility and the time between two financings, however, is not as obvious. It is clear that the risk of loss usually decreases with time as described in the previous hypothesis, leading to larger returns for longer periods between financing rounds, and thus to larger implied volatilities. However, since the Cox-Ross-Rubinstein implied volatility is defined in this binomial tree as the ratio of the logarithm of k (the return) and the square root of t (time), longer periods between two financing rounds may actually lead to smaller implied volatilities. Thus, we hypothesise as follows.

Hypothesis 2b: *Cox-Ross-Rubinstein implied volatility is dependent on the time length of the period between two financing rounds.*

The riskiness of a private venture should decrease also if the commitment of outside investors increases. If a venture has already undergone many venture capital financing rounds, the risk of loss should have decreased substantially as a result of the certification and commitment provided by the investors (Stuart *et al.*, 1999). According to the certification argument, changes in value should be smaller for those companies that

have already had many rounds of venture capital financing. As a consequence, we hypothesise that the more the venture has already raised venture capital financing rounds, the larger should be the risk-neutral probability, and the smaller the implied volatility of returns.

Hypothesis 3a: *The risk-neutral probabilities of the binomial model are positively related to the number of financing rounds that the venture has raised previously.*

Hypothesis 3b: *Cox-Ross-Rubinstein implied volatility is negatively related to the number of financing rounds that the venture has raised previously.*

3 DATA

3.1 Data sources

The empirical sample consists of 597 investment rounds made into 176 U.S. venture capital backed companies that were listed on a U.S. stock exchange between January 2, 1998 and December 31, 1999. Of these rounds, 421 represent venture capital financings and 176 IPOs. The sample includes all companies that went public during that period and for which valuation data for at least one venture capital financing round and the IPO were available.

We obtained the valuation data from Securities Data Corporation's (SDC) Venture Economics databases. This extensive source of venture capital investment data has been used in previous venture capital research (see e.g. Bygrave, 1989; Gompers, 1995; or Gompers and Lerner, 1998), but previous studies have not used the company valuations from this database, as they were made public only at the end of 1999. The sample of valuations of this paper consists of the disclosed post-money valuations[5] that were available in the database in January 2000. The source includes valuation data on only part of the venture capital financing rounds that the ventures have raised, and for some ventures there is only one financing round with a disclosed value. However, limiting the sample to those ventures that had an IPO provides an additional data point for each venture. As a result, we have at least two valuation data points for each venture. Thus, we can obtain at least one risk-neutral probability and implied volatility estimate for all the ventures of our sample.

In addition to the valuations, we used the Venture Economics data to determine the amount of financing in each round, the number of venture capital rounds that each company had raised, the dates of the financing rounds, the venture's stage of development in each round, and the venture's industry classification according to Venture Economics.

[5] 'Post-money valuation' is a frequently used concept in venture capital. It is defined as the price per share of the financing round multiplied by the number of shares outstanding after the financing round.

In all argumentation and analysis that follows, we use the classification of venture capital financing stages used by Venture Economics. The firm classifies each financing round as an early stage financing, an expansion stage financing, or a later stage financing. These classes are further divided into smaller subgroups. We code the development stages with dummy variables in order to separate the early, the expansion, and the late stages of development. The coding is presented in Table 1.

Table 1 The coding of the development stages

The table presents the classification that Venture Economics uses to classify the stages of development of ventures. The right-hand columns represent the coding of these stages used in this paper.

		Dummy variable coded	
Stage of development	Consists of stages	EARLY	LATER
Early stage	Seed Start-up First stage / Early stage	1	0
Expansion	Second stage Third stage / Expansion	0	0
Later stage	Bridge / Buyout IPO	0	1

The data on the initial public offerings was obtained from Securities Data Corporation's Venture IPO database. We used the data on the offer price and the number of shares outstanding after the IPO to calculate the venture's market capitalisation at IPO. This figure was used as the exit value of the venture. The IPO date was taken from the same database. Furthermore, we validated the IPO share price and the number of shares outstanding after the offering using data from the IPO prospectus of each venture. Prospectuses were obtained from the U.S. Securities and Exchange Commission's EDGAR service.

The risk-free interest rate data were obtained from the U.S. Federal Reserve Bank of Chicago files. Daily closing yields of the 5-year U.S. Treasury bill were used in all calculations. If the date of a financing round, as disclosed in the Venture Economics database, appeared to be a holiday, no risk-free rate for this date was available. In these cases, we used the closing yield of the nearest possible date.

3.2 Limitations of the sample

The data on the venture capital investment rounds are limited in certain respects. Firstly, the observations include only successful ventures that were able to proceed to the initial public offering. This fact may bias the data so that steadily rising valuations may occur more often than if the sample contained also the less successful ventures. Secondly, it may be that the private valuations are disclosed only when they have developed positively as compared to the previous financing round. Disclosing lower valuations than before might invite negative publicity for the venture, and perhaps make it more difficult to attract investors in the future. Thirdly, it seems that valuations

associated with the seed and start-up stages are less frequently disclosed than later-stage valuations. Venture capitalists may wish to disclose company valuations only at later stages when the uncertainty about the quality of the deal is smaller. Fourthly, database and prospectus data contain only a limited amount of information on each venture. Venture capital investments are characterised by private information that is not uniformly distributed across potential investors (Wright and Robbie, 1998), and our data set is unlikely to record all such information. Thus, our sample potentially lacks certain relevant value-related information. However, we stress that the sample entries are still close to the 'best available' public data at the time when this paper was constructed.

3.3 Operationalisation of variables

We define the necessary variables in Table 2. Two dependent variables, the risk-neutral success probability and the Cox-Ross-Rubinstein implied volatility, are examined separately in the analyses. These variables are defined in equations (4) and (5). The parameter k is calculated as the venture's post-money value at a financing round divided by the post-money value at the previous financing round, if the value increases, and as the inverse ratio of these values if the value decreased.

We use four independent variables to test hypotheses 1 – 3. Firstly, we examine the effect of the venture's stage of development with two dummy variables defined in Table 1. 'EARLY' indicates that the venture was in an early stage of development (i.e. seed / start-up / first stage) in the previous financing round. Similarly, 'LATER' indicates that the venture was in a later stage of development (i.e. bridge / buyout / IPO).

Secondly, we test the effect of the period between the two financing rounds (t). It is simply defined as the fraction of years between the two financing rounds. Additionally, we use a transformed form of the time variable, $\frac{1}{\sqrt{t}}$, in the case of the implied volatilities to better capture the effect of time on the significance of the other regression variables. This transformation derives from the definition of the implied volatility in equation (5).

Thirdly, we analyse the effect of prior venture capital commitments using the number of previous venture capital financing rounds. All rounds that Venture Economics had recorded as separate financings were included in the variable.

In addition to the independent variables, we control for several other phenomena. Firstly, we take into account the total amount of venture capital financing injected into the venture in the financing round. This is important because post-money valuation is defined as the value of the venture after a financing round, including the amount of money invested. This implies that large venture capital investments automatically lead to large increases in post-money valuations. Thus, controlling for the total amount of venture capital financing in each round mitigates the potential bias in post-money valuations caused by the typical increase in the amount of capital provided in later rounds.

Secondly, we control for the industry sector of the venture. Ruhnka and Young (1991) hypothesise that ventures in different industries may have different risk characteristics. Discussions with practitioners indicate strong support for this claim. To take these differences into account, we include industry dummy variables in the regression models. The variables INFO and BIO classify the ventures into information technology companies, medical- health-life-sciences companies, and companies that belong to neither of these categories[6]. In more detailed analysis, finer industry divisions had no qualitative effect on the results.

Finally, we take into account the public market return between the two financing rounds. It is evident that there should be a tight correlation between venture capital valuations and public market valuations (Gompers and Lerner, 2000). Thus, omitting public market conditions might lead to a situation where the risk-neutral success probabilities or implied volatilities only capture general short-term trends in company market valuations. We operationalise the public market return as the return of the Nasdaq Composite index between the previous financing round and the current round. We define this return as $(I_1-I_0) / I_0$, where I_0 is the value of the index at the time of the prior round, and I_1 the value of the index at the time of the current round.

Table 2 Operationalisation of variables

Dependent variables	Name	Explanation
Risk-neutral success probability	q	Defined by equation (4). k is calculated as the ratio of the current round post-money valuation and the previous round post-money valuation.
Cox-Ross-Rubinstein implied volatility	σ	Annual implied volatility in percent. Defined by equation (5). k is calculated as above.
Independent variables	**Name**	**Explanation**
Venture was at an early stage of development?	EARLY	Dummy variable. = 1, if the venture was at an early stage of development at the prior financing round. = 0 otherwise.
Venture was at a later stage of development?	LATER	Dummy variable. = 1, if the venture was at a later stage of development at the prior financing round. = 0 otherwise.
Time from the previous round	t	Fraction of years between the prior and the current financing round
Number of prior financing rounds	RND	Number of venture capital financing rounds the company raised prior to the current round
Control variables	**Name**	**Explanation**
Return from the Nasdaq Composite index between two consecutive financing rounds	CH_NAS	Absolute return from the index I. Return = $(I_1-I_0)/I_0$ where 0 = prior round and 1 = this round
Industry class was information technology?	INFO	Dummy variable. = 1, if the venture operates in information technology. = 0 otherwise.
Industry class was biotechnology / medical?	BIO	Dummy variable. = 1, if the venture operates in biotechnology / medical. = 0 otherwise.
Total amount of venture capital financing raised in the round	RNDTOT	Total investments in millions of U.S. dollars

[6] Venture Economics refers to these as 'non-high-technology companies'.

3.4 Summary information and descriptive statistics

The data contain 597 financing rounds and corresponding valuations of 176 ventures. Of these financings, 176 represent IPOs and 421 represent venture capital investment rounds. We have, on average, 3.4 observations per firm. Thus, there are on average 2.4 observations at venture capital financing rounds and one at the IPO. The observations are concentrated in the latter part of the 1990s. Over 94% of the data points are from the year 1996 or later.

The sample ventures operate mainly in the high-technology industries, as is typical for venture capital backed companies in general. Venture Economics classifies 163 of the total 176 ventures as information technology companies, six as medical, health, and life sciences companies, and seven as non-high-technology companies. Seventy-seven of the information technology ventures operate in an Internet specific industry. Almost all the medical, health, and life sciences ventures operate in the biotechnology industry. Non-high-technology ventures included companies from several industries.

Table 3 presents descriptive statistics for the sample. The average overall risk-neutral success probability is 0.28 and the corresponding annual implied volatility 158%. The companies have raised on average 4.2 financing rounds, and the average interval from the previous financing round is 0.94 years. Because of the extremely bullish market conditions during the sample period, the NASDAQ Composite index returned on average 53.6% in the period between the current and the previous financing round. The companies raised on average 40 million dollars in all the financings (median 24 M), and on average 74M USD in the initial public offering (median 60M USD). The average market capitalisation at the IPO was also comparatively large, 476M USD (median 330M USD). In addition, the step-ups in post-money valuations from one venture capital financing to the next were notable: on average companies experienced over four-fold increases. Thus, the sample venture capitalists realised generous returns on paper even in the private financing stages. The risk-free rate of return was modest during the sample period and averaged only 5.65%.

The left side of Figure 4 plots the relationship between k (a proxy for return) and the risk-neutral success probability q (a proxy for risk) for the sample observations. The graph shows that the risk-neutral success probabilities are closely grouped along a decreasing and convex trajectory. The right side of Figure 4 shows the relationship between k and the annual Cox-Ross-Rubinstein implied volatility σ. The data points are scattered widely across the figure, but nevertheless imply a positive relationship between risk and return.

Table 3 Descriptive statistics

Variable	Name	Unit	Mean	Median	Std. deviation
Risk-neutral success probability	q	0…1	0.28	0.26	0.16
Cox-Ross-Rubinstein implied volatility	σ	Annual %	158%	135%	121%
Number of prior financing rounds	RND	Integer	4.20	4.00	2.16
Time from the previous round	t	Years	0.94	0.73	0.94
Return from the Nasdaq Composite index between two consecutive financing rounds	CH_NAS	%	53.6%	32.2%	65.7%
Total amount of venture capital financing raised in the round	RNDTOT	MUSD	40.9	24.0	46.1
Risk-free rate of return	r_f	Annual %	5.65%	5.71%	0.53%
Times increase in value in the good state of nature	k	> 1	4.78	3.12	5.42
Dummy variable			N		
Venture was at an early stage?	EARLY	0/1	115		
Venture was at a later stage?	LATER	0/1	67		
Industry class was information technology?	INFO	0/1	393		
Industry class was biotech / medical?	BIO	0/1	11		

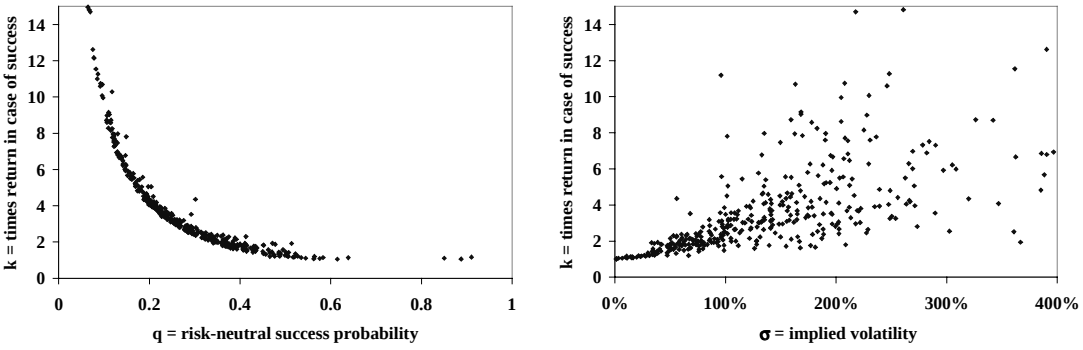


Figure 4 Left side: The relationship between k *(a proxy for return) and* q *(a proxy for risk) for the empirical sample. Right side: The relationship between* k *and annual* σ *for the empirical sample.*

4 INTERPRETATION OF THE RESULTS

To test hypotheses 1 – 3, we perform ordinary linear regression analyses on the risk-neutral success probabilities and the implied volatilities calculated from the data. We calculate the risk-neutral success probabilities from the data using equation (4) and the implied volatility using (5). We check that the variables fulfil necessary distributional assumptions, and make a logarithmic transformation when it is necessary to ensure normally distributed error terms.

We estimate altogether five models (Table 4). The first three are OLS regressions in which the dependent variable is the natural logarithm of the risk-neutral success

probability. We first insert all independent and control variables into the regression model. In the second model, we omit the public market return variable CH_NAS since it is strongly correlated with *t*. The effect of *t* alone can thus be observed from regression two. Model 3 is similar to model two expect that the dependent variable is not *q* but its natural logarithm. This transformation ensures that the distributional assumptions of the OLS regression are fulfilled better.

Models four and five are full OLS regressions in which the dependent variable is the Cox-Ross-Rubinstein implied volatility. Model four includes the same explanatory variables as model one, and model five repeats this analysis using a transformed time variable $\frac{1}{\sqrt{t}}$ that comes from the definition of the implied volatility (5). From model four one can see the linear relationship between the period, *t*, and the implied volatility. From model five one can verify that the independent variables remain significant although the variation due to *t* itself is explained in full with $\frac{1}{\sqrt{t}}$.

The results provide strong support for hypotheses 1a, 1b, 3a, and 3b. The risk-neutral probabilities are indeed smaller for early-stage ventures and positively related to the number of prior financing rounds. Implied volatility is larger for early-stage ventures and negatively related to the number of prior financing rounds. Furthermore, hypothesis 2b is supported, but hypothesis 2a is rejected. Implied volatility is significantly and negatively related to the period between two financing rounds (*t*), and positively related to $\frac{1}{\sqrt{t}}$. However, the risk-neutral probabilities are not statistically significantly related to the period between the two financing rounds in models one and two. Only when the risk-neutral success probabilities are transformed using a logarithmic transformation, and the public market return variable is omitted in model three, *t* appears to be significantly and negatively related to *q*, as hypothesised. However, including the public market return variable makes the significance disappear, and thus we cannot accept hypothesis 2a.

The control variables indicate that the total amount of venture capital financing injected into the company in the financing round is a significant determinant of the risk-neutral success probabilities and the implied volatilities. Larger amounts of money injected into a venture tend to result in higher changes in post-money valuations, which increases implied volatility and decreases the risk-neutral success probabilities. The information and communications technology industry dummy is significant and negatively related to the risk-neutral success probabilities and positively related to implied volatility. The biotechnology industry dummy is also positively related to implied volatility in model four, but not significantly negatively related to the risk-neutral success probabilities. Additionally, the public market return represents a weakly significant control variable.

Table 4 Regression results for the determinants of the risk-neutral success probabilities and implied volatility. t*-statistics are in parentheses.*

			Dependent variable: risk-neutral success probability q		Dep. variable: Ln (q)	Dependent variable: Cox-Ross-Rubinstein implied volatility σ		
Independent variables		Exp. sign	(1)	(2)	(3)	Exp. Sign	(4)	(5)
Constant			0.834	0.869	1.03		-1.30	-3.65
			(10.9)	(12.2)	(3.70)		(2.20)	(-7.34)
Number of prior financing rounds	RND	+	0.017	0.017	0.067	-	-0.045	-0.061
			(4.76)	(4.93)	(4.93)		(-1.76)	(-2.67)
Venture was at an early stage of development?	EARLY	-	-0.041	-0.039	-0.158	+	0.320	0.326
			(-2.27)	(-2.15)	(-2.24)		(2.27)	(2.74)
Venture was at a later stage of development?	LATER	+	0.006	0.004	0.041	-	0.060	-0.156
			(0.30)	(0.19)	(0.52)		(0.38)	(-1.16)
Time from the previous round	T	-	0.008	-0.006	-0.075	-/+	-0.621	
			(0.63)	(-0.75)	(-2.51)		(-5.90)	
Time from the previous round, transformed	$\frac{1}{\sqrt{t}}$					+/-		1.05
								(14.2)
Control variables								
Return from the Nasdaq index between two consecutive rounds	CH_NAS		-0.026				0.369	0.094
			(-1.26)				(2.31)	(1.12)
Industry class was information technology?	INFO		-0.088	-0.089	-0.373		0.573	0.580
			(-2.55)	(-2.56)	(-2.77)		(2.14)	(2.54)
Industry class was biotechnology / medical?	BIO		-0.043	-0.050	-0.312		1.23	0.504
			(-0.77)	(-0.90)	(-1.45)		(2.87)	(1.36)
Log of the total amount of VC financing raised in the round	LNRNDTOT		-0.053	-0.056	-0.229		0.281	0.341
			(-7.79)	(-9.32)	(-9.69)		(5.36)	(7.99)
N			421	421	421		421	421
F-statistic			15.2	17.2	19.2		14.1	38.7
R^2			0.23	0.23	0.25		0.22	0.43

The support for the hypotheses implies two main points. Firstly, the binomial pricing model seems to be consistent with prior knowledge on the risk-return profile of venture capital investments. Secondly, although many of the assumptions of the Black-Scholes and Cox-Ross-Rubinstein option-pricing models are not likely to be valid in the case of venture capital investments, Cox-Ross-Rubinstein implied volatilities calculated from actual investment data decrease with the venture's stage of development and prior venture capital commitments, as hypothesised. It is at least evident that the binomial pricing models examined are not in conflict with the existing knowledge on the risk-return structure of venture capital investments.

5 EXPLANATORY POWER AND COMPARATIVE FIT OF THE MODEL

5.1 Analysis method

Although the binomial pricing model seems to be consistent with theory and empirical evidence, more information on the performance and accuracy of the model is needed to apply the methodology in practice.

We next demonstrate what kind of fit one could achieve by mechanically applying the binomial pricing model to venture capital investment data. That is, we demonstrate the accuracy of the results one could expect when the binomial pricing model is applied to venture capital settings. The tests do not attempt to replicate real-life analysis situations, in which more detailed information on the actual quality of the target ventures would be available. Rather, we attempt to compare the performance of the risk-neutral binomial model to the performance of a similar model utilising traditional risk-adjusted discount rates and actual success probabilities.

We analyse the explanatory power and comparative fit of the risk-neutral binomial valuation model by constructing one-step ex post forecasts for the parameter *k*, which represents the times increase in the venture's value in the good state of nature. These forecasts are first compared to the actually realised values of *k*. Secondly, we compare them to the values of *k* predicted by a corresponding 'traditional' binomial pricing model that utilises actual probabilities and traditional risk-adjusted rates of return. One period of this corresponding traditional model is presented on the right side of Figure 1. We use *k* as the proxy instead of actual valuations since *k* represents a relative measure of the development of the venture's value. This allows us to avoid the bias due to the difference in the size of the ventures.

The analysis proceeds as follows. First, we attempt to generate accurate forecasts on the unknown parameter *q* based on the stage of the venture, the industry sector of the venture, and several other parameters. Next, we calculate the corresponding *k* from the binomial model using these estimated *q*:s as the risk-neutral success probabilities, and compare these to the actually realised values of *k*.[7]

We solve *k* from the binomial model formulas as follows.[8]

$$q_i = \frac{\left(1+r_{f,i}\right)^{t_i} - \frac{1}{k_i}}{k_i - \frac{1}{k_i}} \qquad 0 < q_i \leq 1 \tag{4}$$

$$k_i = \frac{\left(1+r_{f,i}\right)^{t_i} + \sqrt{\left(1+r_{f,i}\right)^{2t_i} - 4q_i\left(1-q_i\right)}}{2q_i} \tag{6}$$

The analysis procedure is similar in the case of the 'traditional' binomial models that use actual probabilities and risk-adjusted rates of return. The only difference is that we use *p*

[7] We additionally performed the analysis using two independent random samples. The original sample was split into two data sets, one of which was used to estimate the parameters for *q*. The other data set was then used to assess the predictive power of the estimated values of *k*. The results were similar to those presented in this paper, and we omitted the random sampling to keep the text more accessible.

[8] Note that the negative root in (6) does not make sense as $k > 1$.

instead of q, as in Figure 1, to denote the state probabilities and that the risk-adjusted rate of return (R_i) is used instead of the risk-free rate in the above equations (4) and (6).

The risk-adjusted rate of return is obtained for each stage of development from previous survey studies by Ruhnka and Young (1987, 1991) and Wetzel (1981). These estimates can be regarded as indications of the best available estimates on the venture capitalists' required rates of return for ventures at different stages development. The rates of return are listed in Table 5. We identify the stage of development of each venture at each financing round on the basis of the Venture Economics classifications, and assign an appropriate required rate of return from Table 5 to the financing rounds. Two values are recorded, one from Ruhnka and Young (1987, 1991) and one from Wetzel (1981).

Table 5 Venture capitalists' required rates of return for different stages of development as reported in earlier research

		Rate of return demanded	
Stage reported in the paper	Coded as stage	Ruhnka & Young (1987, 1991)	Wetzel (1981)
Seed	Seed	73.0%	50.0%
Start-up	Start-up	54.8%	50.0%
Third stage	Second	42.2%	37.5%
Fourth stage	Expansion	35.0%	30.0%
Exit stage	Later	35.0%	22.5%

5.2 Calculation of the parameter estimates

Using similar regression analysis as in the hypothesis testing section, we estimate the parameters of the regression model that would best determine the unknown risk-neutral success probabilities q. We use the risk-neutral probabilities as the dependent variable, and the same independent and control variables as in the hypothesis testing.

A similar regression analysis is performed for the 'traditional' binomial model, for which we estimate a model that would best determine the unknown actual probabilities p. The dependent variable p is calculated from the data using (4) in precisely the same way as in the case of the risk-neutral probabilities q, but the risk-adjusted rate of return is used instead of the risk-free rate of return. In the regression models, the independent variables are the same as in the case of the risk-neutral probabilities.

The results of the regressions are presented in Table 6. They indicate that the risk-neutral probabilities may be approximated with the equation

$$q = 0.834 + 0.017RND - 0.041EARLY + 0.006LATER + 0.008t - 0.026CH\_NAS - 0.088INFO - 0.043BIO - 0.053LNRNDTOT \quad (7)$$

For the 'traditional' model utilising Wetzel's risk-adjusted rates of return, the actual success probabilities may be approximated with the equation

$$p_w = 1.29 + 0.019RND - 0.071EARLY - 0.001LATER + 0.129t - 0.099CH\_NAS - 0.197INFO - 0.141BIO - 0.081LNRNDTOT \quad (8)$$

and for the 'traditional' model utilising the risk-adjusted rates of return of Ruhnka and Young (1987, 1991) with the equation

$$p_{RY} = 1.26 + 0.015RND - 0.063EARLY - 0.009LATER + 0.100t \\ - 0.099CH\_NAS - 0.183INFO - 0.154BIO - 0.079LNRNDTOT \quad (9)$$

Table 6 Linear models for the risk-neutral and actual success probabilities

The table presents the linear models that are later used to generate estimates of the unknown actual and risk-neutral success probabilities. Model one is used to generate estimates on q, the risk-neutral success probability. Model two is used to generate estimates for p_W, the actual success probability for the binomial model that utilises Wetzel (1981) risk-adjusted rates of return. Model two is used to generate estimates for p_{RY}, the actual success probability for the binomial model that utilises Ruhnka and Young's (1987, 1991) risk-adjusted rates of return. *t*-statistics are in parentheses.

		Dependent = q	Dependent = p, Wetzel	Dependent = p, R&Y
Independent variables		(1)	(2)	(3)
Constant		0.834	1.29	1.26
		(10.9)	(10.8)	(11.1)
Number of prior financing rounds	RND	0.017	0.019	0.015
		(4.76)	(3.48)	(2.84)
Venture was at an early stage of development?	EARLY	-0.041	-0.071	-0.063
		(-2.27)	(-2.49)	(-2.30)
Venture was at a later stage of development?	LATER	0.006	-0.001	-0.009
		(0.30)	(-0.04)	(-0.29)
Time from the previous round	*t*	0.008	0.129	0.100
		(0.63)	(6.07)	(4.92)
Control variables				
Return from the Nasdaq index between two consecutive rounds	CH_NAS	-0.026	-0.099	-0.099
		(-1.26)	(-3.05)	(-3.21)
Industry class was information technology?	INFO	-0.088	-0.197	-0.183
		(-2.55)	(-3.63)	(-3.54)
Industry class was biotechnology / medical?	BIO	-0.043	-0.141	-0.154
		(-0.77)	(-1.62)	(-1.86)
Log of the total amount of VC financing raised in the round	LNRNDTOT	-0.053	-0.081	-0.079
		(-7.79)	(-7.67)	(-7.80)
N		421	421	421
F-statistic		15.2	22.4	19.9
R^2		0.23	0.30	0.28

These equations are used to calculate an estimate for q and the two p.s for each case in the sample. These estimates of q and p are then used to generate three different estimates of the corresponding k, the return in the good state of nature, using equation (6). The three estimates of k are then compared to the actually realised values of k and to each other. We use the actually realised 5-year bond yield as the risk-free rate, the appropriate risk-adjusted return from Table 5 as the risk-adjusted rates of return, and the actually realised period between the two financing rounds as t.

Our reasoning is as follows. If the estimates of k are close to the actual k, the models perform well. If they are on average systematically different from the actual k, the models perform badly. We perform both an analysis of bias and efficiency and a regression analysis on the estimates and the actual values.

5.3 Analysis of bias and efficiency

Firstly, we analyse the bias and efficiency of the estimates of *k*. Table 7 presents the mean and median estimation errors and standard deviations for the sample. On average, the forecast error is 2.9% (median -6.9%) for the model utilising risk-neutral probabilities, indicating that the model produces rather unbiased estimates of actual valuations. The results for 'traditional' models utilising actual success probabilities and risk-adjusted rates of return are similar. The mean error for the 'Wetzel' model is 2.2% (median -8.8%) and for the 'Ruhnka and Young' model 1.7% (median -11%).

The standard deviation of the forecast error is large for all models. This implies that although the forecasts seem to be fairly right on average, errors are large in both directions when they occur. The result is not a surprise, since previous research on venture capital has shown that the outcomes of venture capital investments include both extreme returns and total losses – these investments result in anything but the average. The model utilising risk-neutral parameters performs only slightly better than the 'traditional' models.

Table 7 Estimation error statistics

The table presents the mean and median estimation errors and standard deviations of the error when the estimated k and the actual k are compared to each other. The estimation errors are calculated as follows: estimation error = (estimated k – actual value of k) / (actual value of k).

Model	Mean error	Median error	Std dev. of error
Using risk-neutral probabilities and risk-free rate of return	2.9%	-6.9%	65%
Using actual probabilities and Wetzel (1981) rates of return	2.3%	-9.5%	70%
Using actual probabilities and Ruhnka and Young (1987, 1991) rates of return	1.7%	-11.4%	69%

5.4 Analysis of explanatory power and comparative fit

Finally, we analyse the explanatory power and comparative fit of the risk-neutral and the 'traditional' models by using ordinary least squares regression. Using the actual *k* as the dependent variable and the estimate of *k* as the independent variable, we expect to find a significant linear relationship between the forecasts and the actually realised values for all the models. If the estimates of *k* are good, the regression coefficient should not be significantly different from one and the constant should not be significantly different from zero. This is a frequently used methodology in evaluating security pricing models (e.g. Kaplan and Ruback, 1995).

Table 8 presents the results of the regressions where the variation of the actual *k* is explained with the estimate of *k*. Panel A includes the results for the risk-neutral binomial model, Panel B for the traditional model with Wetzel's (1981) risk-adjusted rates of return, and Panel C for the traditional model with Ruhnka and Young (1987, 1991) risk-adjusted rates of return. Two regressions are presented for each model: 1) the dependent variable is the actual *k,* and the independent variable is the estimate of *k*; 2)

both the dependent and the independent variables are transformed using a logarithmic transformation. This procedure is preferable to better fulfil the distributional assumptions of the regression model.

Table 8 shows that all the models have at least some predictive power, and that the regression coefficients are highly significant. The models on the left side of the table show that the risk-neutral binomial model outperforms the others in explanatory power. However, none of the models is well-posed since either the coefficients are statistically different from one or the constants are statistically different from zero.

The models on the right side of the table indicate again that the explanatory power of the risk-neutral binomial model is significantly greater than that of the others. In addition, the risk-neutral model is now well-posed whereas the other models are not.

We conclude that the risk-neutral binomial valuation model seems, indeed, to have explanatory power in one-step valuation forecasts, although the modest regression R-squared indicates that actual deviations from the correct value may occasionally be large. Furthermore, the fit of the risk-neutral model is better than the fit of the traditional models that utilise risk-adjusted rates of return and actual success probabilities.

Table 8 Comparative fit of the valuation estimates

The table provides the results of the regressions where the actual k is explained with the estimate of k. The estimates are calculated using the values of q or p from the regression models presented in Table 6. Left side regressions: actual $k = a + b *$ estimate of k. Right side regressions: ln(actual k) $= a + b *$ ln(estimate of k). A model is well-posed if the coefficient is not statistically different from one, and if the constant is not significantly different from zero. Panel A presents the results for the risk-neutral model and Panels B and C for the traditional models when the risk-adjusted rates of return are used. The R-squared values of the risk-neutral model are statistically significantly larger than those of the other models. N=421 for all columns. Standard errors are in parentheses.

Panel A: Risk-neutral probabilities and risk-free rate of return			
	Dependent: k		Dependent: ln k
Constant	-1.88	Constant	0.046
	(0.632)		(0.097)
Estimate of k	2.11	Ln (Estimate of k)	1.096
	(0.186)		(0.085)
F-statistic	128.3	F-statistic	165.1
R^2	0.234	R^2	0.283
Well-posed?	No (coeff >1, constant < 0)	Well-posed?	Yes

Panel B: Actual probabilities and risk-adjusted rates of return reported by Wetzel (1981)			
	Dependent: k		Dependent: ln k
Constant	0.728	Constant	0.275
	(0.513)		(0.089)
Estimate of k	1.28	Ln (Estimate of k)	0.901
	(0.143)		(0.078)
F-statistic	80.2	F-statistic	132.7
R^2	0.161	R^2	0.241
Well-posed?	No (coeff > 1)	Well-posed?	No (constant > 0)

Panel C: Actual probabilities and risk-adjusted rates of return reported by Ruhnka & Young (1987, 1991)			
	Dependent: k		Dependent: ln k
Constant	-0.513	Constant	0.274
	(0.596)		(0.091)
Estimate of k	1.70	Ln (Estimate of k)	0.908
	(0.175)		(0.081)
F-statistic	93.8	F-statistic	125.3
R^2	0.183	R^2	0.230
Well-posed?	No (coeff > 1)	Well-posed?	No (constant > 0)

6 CONCLUSION

Over the last two decades, option-based pricing models have been applied to many areas outside the traditional field of finance. However, venture capital has remained almost untouched, although it has been identified that these investments include several option-like characteristics. Few serious attempts have been made to model venture capital investments based on option-pricing theory, excluding Willner's (1995) model of start-up venture growth options. Neither has anybody carried out empirical testing of the applicability of option-based pricing models to venture capital settings. Finally, and most importantly, the current knowledge on venture capital lacks efficient methodologies for analysing the risk-return structure of these investments.

We introduce a simple risk-neutral binomial valuation model for the analysis of venture capital investments. We also provide empirical evidence that this model is consistent with previous knowledge on the risk-return profile of venture capital investments.

Furthermore, we find that the model has predictive power regarding actual future valuations. We also find that the predictive power of the model is better than that of corresponding traditional models that use risk-adjusted rates of return and actual success probabilities. The risk-neutral valuation estimates seem to be fairly unbiased, since the mean and median estimation errors are found to be small. Nevertheless, the variance of the estimation error is still large, which is consistent with the 'common sense' observation that venture capital investments often result in extreme outcomes.

This paper has both theoretical and practical implications. The main theoretical implication is that option-based pricing models seem to have relevance in venture capital applications. Even the simple risk-neutral binomial model can provide a feasible methodology for analysing the risk-return structure of these investments. An important implication of this paper for researchers is that the risk and implied volatility associated with privately held companies indeed decrease as the companies reach higher stages of development. Thus, pricing models that assume constant volatility are not likely to be applicable in venture capital or R&D project settings. Practical implications arise from the fact that the model is relatively simple. We argue that it is understandable and also feasible in practice. Venture capital practitioners and R&D project evaluators may thus benefit from the model in decision-making and company analysis settings, especially when quantifying risk and return. On the R&D side, the binomial approach is particularly useful for evaluating projects that are organised as internal or external ventures that receive financing in stages.

The main limitations of this paper arise from two sources, the simplicity of the model and the properties of the empirical sample. As this paper is the first empirical test of option-based venture capital pricing models, we attempt to keep the theoretical model as simple as possible. The binomial framework, which allows only two possible outcomes after each valuation observation, may be too simplistic for sophisticated pricing analysis. Our empirical results also demonstrate that the valuations of venture capital backed companies often result in extreme outcomes that are difficult to capture with any ex ante pricing model.

Secondly, the data set is limited in certain respects. The observations consist of only successful ventures that were able to proceed to the initial public offering. If we could have constructed a sample that contained observations also from ventures that did not succeed, the reliability of the results would increase. However, such a sample is hard to construct, since it is impossible to observe the value of a private company that is no longer able to attract financing. Alternative sources, such as large-scale surveys, could potentially be useful. These methods could alleviate some of the possible bias toward the best companies, which may be a problem with the publicly disclosed valuations that Venture Economics and other corresponding databases record.

Further research should examine the validity of more advanced option-pricing models in venture capital applications. We have shown that a very simple risk-neutral pricing

model is consistent with empirical observations. However, option-based pricing models based on an underlying stochastic process that attempts to capture the venture's value have not been empirically validated. Furthermore, it would be interesting to examine the exercise policy of the venture capitalist's series of options to abandon. When do the venture capitalists decide to invest, and when do they decide not to? Finally, analysing further the risk-return structure of staged venture capital investments using a theoretically sound model, such as a model based on the simple binomial tree idea, would significantly contribute to the current knowledge about venture capital.

REFERENCES

Berger PG, Ofek E, Swary I. 1996. Investor Valuation of the Abandonment Option. *Journal of Financial Economics* 42: 257 – 287.

Black F, Scholes M. 1973. The Pricing of Options and Corporate Liabilities. *Journal of Political Economy* 81: 637 – 654.

Brennan MJ, Trigeorgis L. 2000. Real Options: Development and New Contributions. In Brennan MJ, Trigeorgis L. Eds. *Project Flexibility, Agency, and Competition: New Developments in the Theory and Application of Real Options.* Oxford University Press: New York, NY.

Bygrave WD. 1989. Early Rates of Return of 131 Venture Capital Funds Started 1978-1984. *Journal of Business Venturing* 4: 93 – 105.

Bygrave WD, Stein M. 1989. A Time to Buy and a Time to Sell: A Study of Venture Capital Investments in 77 Companies that Went Public. Pages 288 - 303 in R. H. Brockhaus, Sr. Ed. *Frontiers of Entrepreneurial Research 1989.* Babson College: Wellesley, MA.

Bygrave WD, Stein M. 1990. The Anatomy of High-Tech IPOs: Do Their Venture Capitalists, Underwriters, Accountants and Lawyers Make a Difference? Pages 238 - 250 in N. C. Churchill ed.. *Frontiers of Entrepreneurial Research 1990.* Babson College: Wellesley, MA.

Bygrave WD, Timmons JA. 1992. *Venture Capital at the Crossroads*. Harvard Business School Press: Boston, MA.

Chiampou GF, Kallett JJ. 1989. Risk/Return Profile of Venture Capital. *Journal of Business Venturing* 4: 1 – 10.

Cox JC, Ross SA, Rubinstein M. 1979. Option Pricing: A Simplified Approach. *Journal of Financial Economics* 7: 229 – 263.

Dixit AK, Pindyck RS. 1994. *Investment under Uncertainty*. Princeton University Press: Princeton, NJ.

Gompers PA. 1995. Optimal Investment, Monitoring, and the Staging of Venture Capital. *Journal of Finance* 50(5): 1461 – 1489.

Gompers PA, Lerner J. 1998. The Determinants of Corporate Venture Capital Successes: Organizational Structure, Incentives, and Complementarities. *NBER Working Paper No. W6725.*

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

Houlihan Valuation Advisors / VentureOne Study. 1998. The Pricing of Successful Venture Capital-Backed High-Tech and Life-Sciences Companies. *Journal of Business Venturing* 13: 333 – 351.

Jägle AJ. 1999. Shareholder value, real options, and innovation in technology-intensive companies. *R&D Management* 29: 271 – 287.

Kaplan SN, Ruback RS. 1995. The Valuation of Cash Flow Forecasts: An Empirical Analysis. *Journal of Finance* 50: 1059 – 1093.

Merton RC. 1976. Option Pricing when Underlying Stock Returns are Discontinuous. *Journal of Financial Economics* 3: 125 – 144.

Moel A, Tufano P. 1998. *When are real options exercised? An empirical study of mine closings*. Working paper, Harvard Business School.

Paddock J, Siegel D, Smith J. 1988. Option Valuation of Claims on Real Assets: The Case of Offshore Petroleum Leases. *Quarterly Journal of Economics* 103: 479 – 508.

Plummer JL. 1987. *QED Report on Venture Capital Financial Analysis.* QED Research, Inc.: Palo Alto, CA.

Quigg L. 1993. Empirical Testing of Real Option-Pricing Models. *Journal of Finance* 48: 265 – 296.

Ruhnka JC, Young JE. 1987. A Venture Capital Model of the Development Process for New Ventures. *Journal of Business Venturing* 2: 167 – 184.

Ruhnka JC, Young JE. 1991. Some Hypotheses about Risk in Venture Capital Investing. *Journal of Business Venturing* 6: 115 – 133.

Ruhnka JC, Feldman HD, Dean TJ. 1992. The "Living Dead" Phenomenon in Venture Capital Investments. *Journal of Business Venturing* 7: 137 – 155.

Sahlman WA. 1993. Aspects of Financial Contracting in Venture Capital. Pages 229 – 242 in Chew DH. Ed. *The New Corporate Finance: Where Theory Meets Practice.* McGraw-Hill, New York, NY.

Stuart TE, Hoang H, Hybels RC. 1999. Interorganizational Endorsements and the Performance of Entrepreneurial Ventures. *Administrative Sciences Quarterly* 44: 315 – 349.

Trigeorgis L. 1996. *Real Options: Managerial Flexibility and Strategy in Resource Allocation.* The MIT Press: Cambridge, MA.

Wetzel WE. 1981. Informal Risk Capital in New England. In Vesper KH. Ed. *Frontiers of Entrepreneurial Research 1981*. Babson College: Wellesley, MA.

Willner R. 1995. Valuing Start-Up Venture Growth Options. Pages 221 – 239 in Trigeorgis L. Ed. *Real Options in Capital Investment*. Praeger: Westport.

Wright M, Robbie K. 1998. Venture Capital and Private Equity: A Review and Synthesis. *Journal of Business Finance & Accounting* 25: 521 – 570.

ESSAY 2:

CERTIFICATION AND BARGAINING POWER IN VENTURE CAPITAL: THE IMPACT OF INVESTOR PROMINENCE ON COMPANY VALUATIONS

Abstract: This paper demonstrates how investor prominence affects the valuations of venture capital backed companies. Employing an extensive data set of U.S. venture capital investments between 1990 and 2000, we show that certification ability gives prominent venture capitalists bargaining power that they utilise when investing in ventures for the first time. In line with asymmetric information and signalling theories, we find that the reputation of existing venture capital investors adds value in future financing rounds. Our results are robust to potential selection biases, alternative measures of investor prominence, existence of other value adding mechanisms, and different sampling periods.

A previous version of this essay was presented in the Strategic Management Society conference in San Francisco, CA, United States, October 21 – 24, 2001. The essay was selected as runner-up in the Strategic Management Society / Booz Allen & Hamilton best PhD conference paper competition.

The essay is in process for publication in *Financial Management.*

1 INTRODUCTION

In the presence of informational asymmetries between company insiders and outside investors, signals that convey information on the quality of the company are valuable. Signalling reduces the investors' risk of selecting a 'lemon' (Akerlof, 1970), and lowers the discount investors require to offset this risk (Spence, 1974). The ability of third-party specialists to give such signals, i.e. to certify the value of young, unknown firms in markets that are characterised by information asymmetry between company insiders and investors, has been a popular topic in the finance literature on initial public offerings. A large body of literature has accumulated around initial public offerings on developing and testing models based on the formal certification hypothesis developed by Booth and Smith (1986). Beatty (1989), Carter and Manaster (1990) and Carter *et al*. (1998), among others, have examined how investment bankers and auditors can help to reduce the effect of informational asymmetries inherent in the IPO process. Barry *et al*. (1990) and Megginson and Weiss (1991) have reported that venture capitalists have the ability to certify the price of initial public offerings. Furthermore, Gompers (1996) found that the portfolio companies of older and thus more reputable venture capitalists are associated with significantly smaller IPO underpricing than those of young VCs.

Since it is problematic for company insiders to convey their private information reliably, certifying signals from reliable third parties are valuable for new ventures. However, new ventures cannot obtain credible certification free of charge. For certification to be credible, the certifying third party needs to have reputational capital at stake, and needs to be at risk of being adversely and materially affected if the certification proves false (Megginson and Weiss, 1991). A rational third party with certification ability will recognise its valuable role and the risks associated with false certification, and will demand compensation for this service.

Besides the wide body of literature on the price-certifying role of third-party specialists, previous research has mainly focused on the initial public offering and the public markets (Beatty and Ritter, 1986; Booth and Smith, 1986; Beatty, 1989; Carter and Manaster, 1990; Megginson and Weiss, 1991; Michaely and Shaw, 1995; Beatty and Welch, 1996; Carter *et al*., 1998; Livingston and Miller, 2000). It has largely ignored the venture capital setting and the highly uncertain private financing stages, although certification is expected to be most valuable when there is little public and symmetric information available about the investment targets. Another closely related but less investigated phenomenon is the bargaining power of the third parties over the price of the certification they provide. There is evidence regarding underwriter compensation in IPOs, but to our knowledge only theoretical work on the bargaining power of venture

capital investors (Hellmann, 1998; Kirilenko, 2001).[9] In the venture capital setting, the potential discount on the company valuation that venture capital investors need to pay for their ownership share represents compensation for their certification. If prominent venture capitalists are particularly valuable for the ventures because of their better certification capability, investor prominence will be negatively related to the valuation of the venture when the VC firm enters the venture as a new investor. Similarly, the prominence of previous investors will be positively related to the future valuations of the venture if certification adds value, and if the existing investors attempt to decrease the dilution of their ownership share in subsequent financings.

This paper contributes to the literature by extending the empirical literature on asymmetric information and signalling from the context of initial public offerings and public markets to the context of privately held companies. We also contribute to the literature on certification by explicitly analysing how prominence affects the compensation third parties require for their certification. Furthermore, we provide methodological contributions on investor prominence measures that can be used as proxies for price-certifying ability.

The paper is organised as follows. Section 2 builds the testable hypotheses based on earlier research. Section 3 presents the data and the methods used. Section 4 presents and discusses the empirical results. Finally, conclusions and implications are discussed in section 5.

2 THEORY AND HYPOTHESES

In this paper, *prominence* refers to the reputational capital that venture capitalists have at stake when making investments. This reputational capital consists of the appreciation the venture capital firm has in the marketplace, and is driven by the activity and in particular the proven success of the firm's operations. *Certification* refers to the ability of third parties to reduce the quality uncertainty over parties associated with them. Although the word 'certification' was used already by Akerlof (1970) in the context of institutions counteracting informational asymmetries, the formal certification hypothesis by Booth and Smith (1986) established the concept in the context of financial markets and intermediaries. Booth and Smith (1986) modelled the ability of underwriters to certify the price of risky issues in markets characterised by asymmetric information between insiders and prospective outside investors.

These arguments, derived from asymmetric information theory (Akerlof, 1970), assume that company outsiders and insiders have different objectives and possess different information. Because of such informational asymmetries, prospective investors cannot

[9] When this paper was already in the review process for publication, we became aware of a related working paper by David Hsu (2002). Hsu examines the willingness of entrepreneurs to pay for venture capital affiliations using a survey sample of U.S. financing offers. Discussion on our methodology in comparison to Hsu (2002) is included in the Methods section.

completely rely on the information they gain from the insiders of a new venture (Gompers, 1995). Investors recognise the asymmetry inherent in the investment situation and are willing to pay less than they would if information were symmetric. Informational asymmetries thus result in a loss of value, or even a market failure (Akerlof, 1970).

However, if a third party can credibly signal that the venture is of good quality, part of the loss of value can be alleviated (Spence, 1974; Booth and Smith, 1986; Beatty, 1989; Carter and Manaster, 1990; Megginson and Weiss, 1991; Carter *et al.*, 1998). An important determinant of credible signalling, or certification, is the reputation of the third party. Chemmanur and Fulghieri (1994) argue that investors use an investment bank's past performance in the equity market to determine its credibility as an underwriter. Thus, investment banks improve their reputation by choosing strict, but costly valuation standards for firms they underwrite (Booth and Smith, 1986; Livingston and Miller, 2000).

In the context of venture capitalists and their portfolio companies, informational asymmetries exist between existing shareholders and prospective outside investors principally in the same manner as those that exist between the insiders and outsiders of any firm. Insiders are better informed on the future prospects of the venture, and rational outside investors recognise the possible incentives of the insiders to overstate the value of the firm when issuing equity.

Following the general theories developed to explain the role of financial intermediaries in resolving informational asymmetries between company insiders and outside investors, several authors have analysed the role of venture capitalists as such intermediaries. Barry *et al.* (1990) and Megginson and Weiss (1991) focused on the ability of venture capitalists to resolve informational asymmetries in initial public offerings. Because of their certification abilities, venture capitalists help firms to access higher-quality underwriters than firms without venture capitalist backing can typically access. Furthermore, as the general certification hypothesis predicts, the underpricing of venture capital backed IPOs is significantly smaller than that of other IPOs. The market interprets the presence of venture capitalists as an indicator of the quality of the issuing firm. Furthermore, Gompers (1996) analysed the relationship between the prominence of venture capitalists and their incentives to make portfolio companies public, and found that young venture capital firms tend to rush for portfolio company IPOs in order to create initial reputation, and to demonstrate their ability to evaluate the quality of their portfolio companies. Gompers' (1996) results suggest that a venture capitalist's ability to provide reliable certificates of quality on its portfolio companies is valued by the market and a desired goal for venture capital firms.

These studies suggest that by putting their reputational capital at stake, venture capital investors are able to reduce the amount of informational asymmetries inherent in new ventures when they go public. In this paper, we examine the relationship between the

reputational capital of venture capital investors and the valuations of investment rounds with particular focus on the certification ability and the bargaining power of prominent venture capitalists. We extend previous research on certification by applying the certification hypothesis to private financing rounds, i.e. investment situations where informational asymmetries are highest. We develop two specific hypotheses that can be robustly tested despite the various problems and biases inherent in the empirical investigation of venture capital valuations in general.

Our first hypothesis considers the certification ability of existing investors in future financing rounds. Prominent venture capitalists have their reputation at stake when making investments, and thus investments by prominent venture capitalists can be seen as signals of the high quality of the venture (Gompers, 1996). If the signal is recognised in the market, informational asymmetries associated with the venture decrease, and the valuation of the venture increases. The prominence of insider venture capitalists should, thus, have a positive impact on the valuation of the venture in subsequent investment rounds.

Furthermore, previous research has shown that insider venture capitalists have incentives to utilise their certification ability in the private financing stages. Higher valuations of subsequent share issues imply less dilution on existing ownership shares. Insiders would thus be better off the higher the valuation in subsequent rounds unless they in turn needed to invest in the venture. However, investments by insiders are typically smaller than investments by new outside investors. To give consistent and reliable signals about the quality of the venture, VCs optimally hold their share of equity constant after their initial investment (Admati and Pfleiderer, 1994). If insider VCs diluted their share of ownership by not investing more, they would convey a negative signal of the quality of the venture. Similarly, an increase in ownership share would imply that the insider VCs favoured themselves in the allocation of potentially underpriced shares. Thus, the adverse selection problem can be alleviated only if insiders hold their share of equity constant. This means that venture capitalists must make reinvestments that correspond to the amount of dilution in each round. These investments are considerably smaller than new investments made by outside investors. As a result, higher valuations of subsequent financing rounds that involve new investors typically benefit insider VCs.

Our second hypothesis considers the bargaining power of venture capitalists that stems from their presumed capability to certify the quality of new ventures. If prominent investors are valuable to their portfolio companies, these VCs have more bargaining power over the entrepreneurs and other insiders than less prominent ones. Accordingly, prominent venture capitalists are likely to utilise their negotiation power to push down the entry valuation and to increase the prospective return on investment for themselves.

The potential ability of top-end venture capitalists to push entry valuations down is logical from the viewpoint of the certification criteria in Megginson and Weiss (1991).

According to the criteria for reliable investor certification, it must be costly and difficult for the venture to purchase the services of a certifying agent, and the cost must be an increasing function of the extent and quality of the certification. Since venture capitalists can be regarded as such certifying agents, at least in the context of initial public offerings (Megginson and Weiss, 1991; Gompers, 1996), prominent VCs may enter deals with more favourable terms than less prominent investors.

More precisely, this paper tests the following two hypotheses.

Hypothesis 1: *(Certification ability of prominent investors)*

The prominence of insider venture capitalists in a new venture is positively related to the valuation of the venture in subsequent private financing rounds.

Hypothesis 2: *(Negotiation power of prominent investors)*

Prominent outsider venture capital firms invest in new ventures at lower valuations than less prominent outsider firms.

3 METHODS AND DATA

3.1 Methods

As Gompers and Lerner (2000) point out, the analysis of venture capital valuations poses estimation challenges that are considerably different from traditional studies on the pricing of publicly traded assets. Firstly, the set of venture capital backed firms is not constant in our analysis, as ventures frequently enter and exit the sample. Secondly, the time between refinancings is variable and long, on average 9.6 months in our sample.

There are two main options for analysing a set of valuations such as ours. Firstly, *hedonic pricing models* can be applied. The idea of hedonic pricing models was first introduced by Waugh (1928) in the context of vegetable pricing. These models regress all price observations on a set of explanatory variables. Hedonic pricing models assume that it is possible to control for factors that are important in determining the price, and thus omitted variables may lead to biased results and wrong interpretations. To minimise the potential problems of unobserved heterogeneity, we utilise a thorough set of control variables in all hedonic models.

While the hedonic approach is useful in the sense that it can incorporate also firms with only one valuation observation, it cannot take into account all the firm-specific determinants of valuations. One possible way to address this concern is to undertake an *analysis of first differences* (Gompers and Lerner, 2000), and examine valuation changes between two financing rounds. This significantly reduces the effects of unobserved firm-specific characteristics that cannot be taken into account in hedonic models.

The first differences approach is naturally not without drawbacks. Firms for which at least two valuation observations exist are likely to be more successful than others, since venture capital valuations can be observed only when the venture has succeeded in obtaining a follow-up financing round. Ventures that have gone bankrupt, have been merged, or have become "living dead" after the first financing round do not produce valuation data, and may systematically differ from the firms we observe with at least two valuations. However, the first differences analysis provides a useful and complementary method to test the hypotheses, especially when combined with an appropriate correction for selection bias.

To overcome the potential problems of selection bias, we utilise Heckman's sample selection methodology in all regression analyses (Heckman, 1979). Our Heckman approach is a full maximum likelihood method, in which the first equation estimates the probability that Venture Economics has been able to record the valuation of the financing round, and the second equation the intended regression using an additional regressor to correct for sample selection. The practical implementation of the Heckman method requires us to include all venture capital financing rounds, including those with no valuation observations, in the initial sample. We use the entire sample of venture capital investments between 1990 and 2000 to estimate the first Heckman equation, and the sub-sample of the financing rounds with valuation observations to estimate the models. To accomplish this estimation, we use the following variables that are available for all financing rounds: the public market index, fundraising in the previous four quarters, round total amount of financing, venture age, development stage dummies, location dummies, industry dummies, and year dummies. In the second equation, coefficients for the substantive regression equation used to test the hypotheses are estimated using the maximum likelihood method. The Heckman methodology allows us to alleviate the potential sample selection biases inherent in the venture capital valuation data set, including biases we have not been able to fully identify. Our approach is equivalent to previous published research utilising venture capital valuations (Gompers and Lerner, 2000). We compute the standard errors for the coefficients using a heteroskedasticity-consistent estimator (White, 1980).

When this essay was in the review process for publication, we became aware of a closely related working paper by David Hsu (2002). Hsu examines the market for venture capital affiliation by empirically examining the price differential between financing offers that new ventures received from venture capitalists of different reputations.

While this paper applies different methods to analyse the valuations of financing rounds, and the changes in valuations between rounds, Hsu (2002) takes the financing offer as the unit of analysis. The advantage of this approach is the possibility to explain the variation in price offered to the startups by different venture capitalists within a short period, while holding the characteristics of the startup fixed. The choice of the unit of analysis reduces the potential problems of unobserved heterogeneity and allows to

estimate the marginal rate of substitution between the price for affiliation and the reputation of the certifying agent.

The disadvantages of Hsu's approach are the relatively small number of observations, the short time frame of the study and the concentration of observations in the peak years of venture capital investment, basing the offer comparisons on price only and not taking into account the other characteristics and conditions of the term sheets, and the potential selection bias problems related to the firms that end up in the final data set. For example, having the offer as the unit of analysis requires allows to include in the sample only startups that received multiple financing offers. Similarly, getting the necessary data made it necessary to administer a survey to firms participating in the MIT E-Lab program. Both of these issues lead to a potential problem of selection bias that should be controlled for. Furthermore, even this approach cannot fully address the problem of unobserved heterogeneity because the problem persists on the offer level due to the potential unobserved differences in the term sheets the startups received.

We strongly believe that the two different approaches to estimating the price and value of certification are complementary to each other, especially because Hsu's (2002) empirical results appear to consistently support our findings. Hsu (2002) concludes that (1) startups are more likely to accept an offer from a VC that has a good reputation even at a low price, (2) top-end VCs make offers at lower pre-money valuations than average VCs. Our results support these patterns.

3.2 Data

The empirical sample consists of 32,311 financing rounds of 13,048 U.S. venture capital backed companies between 1990 and 2000, and it contains valuation data for 5,679 rounds. The venture capital investment data is obtained from the Venture Economics database. This extensive source has been used widely in previous venture capital research (e.g. Bygrave, 1989; Lerner, 1994; Gompers, 1995; Gompers and Lerner, 1999; Kortum and Lerner, 2000). Venture Economics has gathered venture capital investment data since the 1970s using annual reports of venture capital funds, personal contacts to funds' personnel, initial public offering prospectuses, and deals announced in the media. The database contains information on over 150,000 private equity investments (one whole financing round consists of several single investments), and is widely recognised as a leading source of U.S. venture capital investment data[10].

The sample is selected from the universe of all the venture capital investments using three criteria. Firstly, we restrict the data set to contain only U.S. companies in order to reduce unobserved heterogeneity and to improve the reliability of our analysis. Venture

[10] Some academic studies use data from VentureOne, Inc. (e.g. Gompers and Lerner 2000). This firm, established in 1987, collects similar data to those of Venture Economics', but uses a different methodology. Discussion of the relative quality of these two alternative databases can be found in Gompers and Lerner (1999, 2000) and Lerner (1994, 1995).

Economics has extremely comprehensive coverage of U.S. investments, and the U.S. market represents the majority of the global venture capital market. Secondly, we limit the sample to standard venture capital investments. We implement this by removing records that Venture Economics classifies as "leveraged buyout", "secondary purchase", "open market purchase", "private investment in public company", or "turnaround". Our sample thus includes all U.S. investments covered by the established definition of "venture capital" (Gompers and Lerner, 1999) that Venture Economics has recorded in the period of the study. Finally, we check for the consistency of the valuation information for the companies, and exclude all ambiguous records. We classify valuation information as ambiguous if the data on the amount of financing and the valuation of the venture imply that the venture capitalists took more than 100% of the company's equity in the financing. There are 23 such financing rounds in the original sample[11].

In building our IPO market share measures, we cross-check the data on the initial public offerings and IPO dates of those sample ventures that Venture Economics recorded as having conducted an IPO from Securities Data Corporation's (SDC) New Issues database. SDC New Issues is a source of IPO data that records several characteristics of the issuer and the underwriter syndicate.

3.3 Variables

Company market value. Throughout the paper, we use what are known in the venture capital industry as "pre-money" valuations, equal to the product of the price paid per share in the financing round and the shares outstanding prior to the financing round (Gompers and Lerner, 2000). Another possibility would have been to utilise "post-money" valuations, equal to the product of the price paid per share in the financing round and the shares outstanding after the financing round. Pre-money valuations are considered more appropriate for pricing analyses than post-money valuations (Lerner, 1994), and have been used in the previous research on venture capital valuations (Lerner, 1994; Gompers and Lerner, 2000). Pre-money valuation is not directly dependent on the amount invested in the firm during the current financing round. As Gompers (1995) discusses, the amount invested may vary with many considerations, including the fundraising environment. Thus, we examine pre-money valuations throughout the analysis. Venture Economics converts all preferred shares into common shares, and reports the "post-money" valuation of the financing round based on the total number of common shares outstanding after the financing round and the price per share paid in the financing round. We calculate the pre-money valuation by subtracting the amount invested in the financing round from the post-money valuation reported by Venture Economics.

[11] Typically, venture capital financings, as defined in our sample, transfer 10-40% of the venture's shares to the venture capitalists.

Given the length of time that our analysis covers, it is necessary to control for inflation. To do that, we collect the quarterly values of the Gross Domestic Product deflator from the Bureau of Economic Analysis of U.S. Department of Commerce. We then convert all nominal company valuations, public market index values, and amounts of funds raised and invested to 2001 dollars, and run the analyses using these deflated data.

Investor prominence. The key independent variable of our analysis is investor prominence, also known as reputation (Livingston and Miller, 2000:22). In previous literature focusing on certification by third parties, various kinds of proxies have been used to measure prominence and reputation (Carter and Manaster, 1990; Megginson and Weiss, 1991; Michaely and Shaw, 1995; Beatty and Welch, 1996; Gompers, 1996; Livingston and Miller, 2000). In this paper, we put emphasis on selecting a relevant and meaningful prominence measure for venture capital investors, and on testing several alternative measures to ensure the robustness of our results. Testing that the predicted relationships hold irrespective of the operationalisation of the construct increases our confidence in the results.

Previous research in related domains has employed at least three types of prominence measures. Firstly, in research on initial public offerings, underwriter prominence has been tracked using past performance measures such as the IPO market share of each underwriter (e.g. Megginson and Weiss, 1991; Beatty and Welch, 1996; Livingston and Miller, 2000). Past performance is a good proxy for prominence because outside investors and other economic actors can observe and verify track records independently. Market share based measures are also available for various types of certifying third parties, which enables comparisons and makes them practical (Beatty and Welch, 1996).

A second category of prominence measures is based on status orderings among competitors. One example of status based prominence measures is the underwriter ranking of Carter and Manaster (1990), updated by Carter *et al*. (1998). The ranking is based on the notion that IPO underwriters are careful about the position of their name on IPO tombstone advertisements. Therefore, the higher the name is in the list of the syndicate partners, the higher the status of the underwriter. While this approach is appealing, the previous implementation of these status measures has assumed that reputation remains constant throughout the research period, which is frequently not the case for longer periods. While there are no similar tombstones in the context of venture capital investments, researchers in sociology have recently started measuring the status of venture capitalists as the position of the focal venture capital firm in the overall network of venture capitalists. Sociologists have interpreted the position in inter-firm networks as a measure of firm status, and have also used the syndication relationships of venture capital firms in such networks. Essentially, the more syndication connections a VC firm has to other VC firms, and the more central positions these other firms have, the higher is the status of the focal VC firm (Podolny, 2001). While status measures

generally reflect the appraisal of the focal economic actor in its social context, they may not be tightly coupled to past or present performance (Podolny, 1993). While not tightly linked, status and performance are highly correlated, and status both drives future quality and acts as an indicator of the quality of the underlying product or service (Benjamin and Podolny, 1999). Despite the different theoretical reasoning, tombstone-based status measures and past performance measures of prominence have been found to be highly correlated for instance in the context of initial public offerings (Megginson and Weiss, 1991; Carter *et al.*, 1998).

A third alternative prominence measure for venture capitalists has been the age of the venture capital firm (Gompers, 1996). Young venture capital firms have a tendency to "grandstand", or to attempt to create reputations by exiting their portfolio companies earlier than older firms in order to demonstrate tangible performance (Gompers, 1996). Track record is important for venture capital firms if they wish to raise follow-on funds and continue active investment. However, age as such is not a fully consistent estimator of investor prominence. It is not explicitly related to performance, and using age as a measure of prominence would assume that the creation of prominence is automatic and monotonic without a connection to the performance of the investors.

In this study, we employ several prominence measures to demonstrate that the choice of measure does not affect our findings. As our main measure of prominence, we use past performance, which we operationalise as the cumulative share of the venture capital backed IPO market. IPO market share is defined as the cumulative number of the venture capital firm's portfolio company IPOs divided by the cumulative number of all venture-backed IPOs in the sample, where the cumulating starts at the first year of the sample. This approach takes into account both the dynamic nature of prominence and the success of the venture capital investors. In cases where several venture capitalists invest in a venture at the same time (syndication), we use the sum of the investors' IPO market shares as a measure of the total prominence of new investors. The same logic applies when the prominence of existing inside investors is measured.

In addition to the sum of IPO market shares, we test the robustness of our results by running the analyses using four alternative investor prominence measures for both the new outside investors and the inside investors. These measures include the average and the maximum of the cumulative IPO market shares of the investors in the syndicate, the sum of the investors' number of prior portfolio companies (measuring investment experience), and the average firm age of the investors. In unreported analyses, we also run regressions using the maximum age of the investors and the average and the maximum number of prior portfolio companies as prominence measures. The results are similar to those presented in this paper.

To take into account only actual signals conveyed by insiders, we include a venture capital firm's prominence score in the combined prominence score of existing inside investors only when the focal venture capital firm invested in the venture in the

financing round that preceded the current round. This is necessary because only the event of investing in the venture conveys the signal of high quality to the market and to outside investors. If a current round investor no longer invests in future financing rounds, we expect the prominence of this investor to affect the valuation of the venture only in the current and the immediately following round of financing. However, we also ran our regressions by taking into account the prominence of all existing inside investors despite their decision not to participate in later financing rounds, but did not observe qualitative differences in results.

Control variables. The decision of top-end investors to invest in a new venture is not the only possible factor that may affect the valuation of the venture. Therefore, we include several control variables in order to control for the related phenomena.

Venture capital investing has been identified as an extremely cyclical business (Bygrave and Timmons, 1992; Gompers and Lerner, 2000). Reflecting these cycles, venture capital valuations eventually follow changes in public market valuations, which give indications of the possible exit values of the ventures. It is thus essential to control for changes in public market valuation levels. We use the Nasdaq Composite index, measured in 2001 dollars, to control for the varying valuation levels in public markets. Although the Nasdaq index does not entirely follow the industry distribution of our sample companies, we expect it to represent a very closely correlated measure of the expected venture capital exit valuations in the largest public exit market for U.S. venture capital investments.

Another significant factor that affects venture capital valuations is the extent of fundraising in the venture capital industry (Gompers and Lerner, 2000). We use the yearly amount of venture capital fundraising carried out by ordinary U.S. venture capital firms as reported by Venture Economics and converted to 2001 dollars. This measure includes the yearly money inflow into all U.S. venture capital partnerships that Venture Economics tracks. Buyout and turnaround funds are excluded from the figures.

Even though venture capitalists attempt to maximise the expected return on their investment, and thus attempt to minimise the company valuation when they invest, larger venture capital financing injections may lead to higher implied pre-money valuations of the target ventures than smaller injections. One reason for the potential existence of large venture capital injections at inflated valuations is the inflow of funds into venture capital (Gompers and Lerner, 2000). Additionally, inflated valuations may result from the common venture capital rules of thumb regarding certain maximum ownership percentages that investors and entrepreneurs should possess after each financing round, or from the potential tendency of venture capitalists to invest relatively large sums of money at inflated valuations when ventures are expected to grow fast and when they thus require large amounts of capital. The problem of money inflows inflating valuations closely resembles the traditional free cash flow problem of corporate management (Jensen, 1986), which may lead managers to make too many, and thus less

attractive investment decisions when they have a considerable amount of cash to spend. Because the amount of money injected into the ventures may affect their pre-money valuations, we include the round amount of financing as a control variable. To control for inflation, we deflate the amounts using the GDP deflator.

Fama and French (1992) have shown that the stock market returns of small firms differ significantly from those of other concerns. In organisational research, small and young companies have been argued to suffer from *liability of smallness* and *liability of newness,* meaning that small and young companies have problems in obtaining resources because of their lower legitimacy (Stinchcombe, 1965; Aldrich and Auster, 1986). Thus, we control for the age of the venture.

We also control for potential industry effects. We use the classification of Venture Economics, and include dummy variables for the following industry sectors: biotechnology, communications / media, computer hardware, semiconductors / electronics, Internet specific, consumer related, medical / health, and industrial / energy ventures.

Furthermore, we control for the stage of development of the ventures. According to Ruhnka and Young (1991), venture capitalists expect that the risk of loss associated with venture capital investments decreases steadily as a venture reaches higher stages of development. Their results indicate that the aggregate risk of loss is as high as 66% for seed investments, and approximately 20% for bridge financings. Wetzel (1981) reports results in line with Ruhnka and Young (1991). Both report also that venture capitalists' required rate of return declines as the venture reaches higher stages of development. In their empirical study of the implied volatility and risk of venture capital valuations, Seppä and Laamanen (2001) found support for this observation. All these studies additionally indicate that it is more probable that a venture will fail in the early rather than the later stages of development. Therefore, as the venture advances from the first stage of development to the second stage, the risk of loss decreases more than if the venture advances from stage four to stage five. As a consequence, relative changes in value are typically larger in the early stages of the venture's development. Venture Economics classifies ventures into early stage, expansion, and later stage companies, for two of which we code dummy variables.

Finally, we include dummy variables for the sample years to control for other time-dependent factors that may affect company valuations.

3.4 Descriptive statistics

Table 1 reports descriptive statistics regarding the pre-money valuations of the financing rounds of the sample. Clear, logical patterns emerge from the data. Firstly, early-stage rounds have significantly lower valuations than expansion or later-stage rounds. While the median valuation for early-stage rounds is approximately 8 million dollars, the

median later-stage valuation is already close to 44 million. Secondly, valuations clearly vary across industries. Communications/media, consumer related, Internet specific, and semiconductors/other electronics industries have clearly higher median and average valuations than other industries. Thirdly, ventures in California or in one of the East Coast states have higher valuations than average U.S. ventures. Finally, while the median and average valuations fluctuate across years, there is a significant upward surge towards the end of the sample years. The increase in valuations between 1998 and 2000 suggests that the effect of the late years of the sample on the results should be checked carefully. To ensure robustness, we run all regressions using several different sampling periods, and found no substantive differences.[12]

Table 2 compares the sample financing rounds with valuation data to those without valuation data. Although Venture Economics is regarded as the most comprehensive source of U.S. venture capital investment data, the valuations of the financing rounds are available only for approximately 18% of the sample financing rounds. Valuations are more frequently available towards the end of the sample, and most of the differences between the rounds with valuation observations and those without appear to result from the large number of valuation observations in the years 1999 and 2000. These years involved higher public market valuations, higher levels of fundraising, younger companies, larger financing rounds, and more Internet specific companies. Such a bias is expected because Venture Economics made its database of company valuations available only in the beginning of 2000. While we believe that the differences do not in fact yield biases in the final results, it seems appropriate to utilise an efficient sample selection correction methodology in all analyses to ensure the robustness of the results despite not observing the valuation for all financing rounds.

[12] Robustness tests are described later in more detail.

Table 1 Inflation-adjusted pre-money valuations of financing rounds

The table describes the pre-money valuations of the financing rounds categorised by round characteristics. The second column lists the number of rounds for which we have valid valuation data. The third column presents the percentage of rounds with valid valuation data from all financing rounds in the same category in the Venture Economics database. The three rightmost columns list the median, the mean, and the standard error of the pre-money valuations in the corresponding category.

	Number of rounds with valuation data	% of all financing rounds in category with valuation data	Pre-money valuations ($ thousands as of 2001)		
			Median	Mean	Standard error of mean
Stage of development					
Early stage	2,161	18%	8,236	18,120	908
Expansion	2,418	19%	32,629	68,998	2,576
Later stage	1,100	15%	44,370	89,249	3,937
Industry					
Biotechnology	403	19%	20,329	39,961	3,131
Communications and media	721	19%	26,376	78,365	5,117
Computer hardware	193	14%	17,809	37,757	3,802
Computer software and services	1,194	18%	18,170	40,403	1,658
Consumer related	122	6%	15,057	73,017	28,283
Industrial/energy	91	7%	11,301	40,709	9,272
Internet specific	1,888	27%	24,826	64,788	2,680
Medical/health	606	16%	13,090	25,755	1,771
Other products	134	6%	17,793	44,511	6,205
Semiconductors/other elect.	327	19%	23,851	59,727	6,522
Location					
California	2,567	21%	22,752	57,640	2,407
MA, NJ, or NY	971	17%	20,607	55,529	3,446
Other U.S. state	2,141	15%	18,273	47,775	1,936
Year					
1990	27	2%	11,045	25,676	6,626
1991	46	3%	8,403	28,967	6,069
1992	205	11%	11,006	16,738	1,033
1993	158	10%	10,668	19,669	1,959
1994	260	16%	11,610	20,604	1,659
1995	149	8%	9,962	21,856	2,492
1996	386	15%	11,904	29,901	2,974
1997	575	17%	14,709	30,828	2,055
1998	734	19%	15,665	34,627	2,108
1999	1,245	24%	28,614	68,681	4,094
2000	1,894	26%	31,743	77,507	2,929

Table 2 Comparison of financing rounds with and without valuation data

The table compares the characteristics of the financing rounds for which Venture Economics was able to determine the valuation, and the rounds for which Venture Economics was not able to do so. The rightmost column presents the *p*-values of the χ^2- and *t*-tests of the hypothesis that these two groups of financing rounds are identical.

	Rounds without valuation data	Rounds with valuation data	*p*-value from test of equality
Stage of development			
Early Stage	38%	38%	0.798
Expansion	39%	43%	0.000
Later Stage	23%	19%	0.000
Industry			
Biotechnology	6%	7%	0.018
Communications and Media	12%	13%	0.013
Computer Hardware	5%	3%	0.000
Computer Software and Services	20%	21%	0.076
Consumer Related	7%	2%	0.000
Industrial/Energy	4%	2%	0.000
Internet Specific	20%	33%	0.000
Medical/Health	12%	11%	0.000
Other Products	8%	2%	0.000
Semiconductors/Other Elect.	5%	6%	0.149
Location			
California	37%	45%	0.000
MA, NJ, or NY	18%	17%	0.093
Other	45%	38%	0.000
Other round characteristics			
Date of financing	May-96	Dec-97	0.000
Company age (years)	5.6	4.2	0.000
Inflation-adjusted Nasdaq Composite index level	1,938	2,533	0.000
Inflation-adjusted round total amount of financing (MUSD)	6.3	13.3	0.000
Sum of new investors' IPO market share	1.11%	1.85%	0.000
Sum of new investors' cum. no. of portfolio companies	80	177	0.000
Average age of new investors (years)	7.0	9.2	0.000

Finally, Table 3 presents the cumulative IPO market shares of the top 30 U.S. venture capital partnerships between 1996 and 2000, ranked in descending order according to the year 2000 figures. The ranking of the top firms appears to remain relatively unchanged over time. Firms familiar to the general public occupy the top positions: Kleiner Perkins, New Enterprise Associates, and Sequoia Capital are consistently the top three partnerships.

Table 3 Cumulative IPO market shares of top-end venture capital firms (%)

The table presents the cumulative market share of portfolio company initial public offerings for the top 30 venture capital firms in the sample. The venture capital firms are divided into partnerships classified by Venture Economics as "independent private partnerships" and other types of investors. The cumulative market share in a given year is defined as (cumulative number of firm's portfolio company IPOs) / (cumulative number of all sample IPOs). The first observation in the sample is from the year 1990. Note that several VC firms may have participated the same portfolio company IPOs.

	Venture capital firm name	1996	1997	1998	1999	2000
	Independent private partnerships investing own capital					
1	Kleiner Perkins Caufield & Byers	6.8	7.3	7.2	7.0	6.7
2	New Enterprise Associates	8.5	7.7	7.3	7.2	6.7
3	Sequoia Capital	6.0	5.6	5.4	5.4	5.0
4	Lightspeed Venture Partners (FKA: Weiss, Peck & Greer)	5.7	5.5	5.3	4.7	4.6
5	Accel Partners	3.9	4.2	4.1	4.1	3.9
6	Alta Partners (FKA: Burr, Egan, Deleage & Co.)	4.1	3.8	3.6	3.3	3.7
7	Oak Investment Partners	3.9	3.4	3.4	3.4	3.7
8	TA Associates, Inc.	4.5	4.3	4.1	3.8	3.3
9	U.S. Venture Partners	3.2	3.2	3.2	3.0	3.2
10	Mayfield Fund	3.2	3.3	3.2	3.1	3.1
11	Warburg Pincus, LLC	3.3	3.4	3.3	3.1	3.0
12	Institutional Venture Partners	3.4	3.2	3.0	3.1	3.0
13	Venrock Associates	3.1	2.9	2.9	2.8	2.9
14	Summit Partners	4.0	3.7	3.7	3.3	2.8
15	Technology Crossover Ventures (TCV)	2.3	2.4	2.4	2.7	2.7
16	Domain Associates, L.L.C.	3.2	3.5	3.3	2.6	2.5
17	Greylock	2.6	2.2	2.3	2.6	2.5
18	Crown Advisors International, Ltd.	4.2	3.7	3.4	2.8	2.5
19	Bessemer Venture Partners	2.1	2.2	2.1	2.3	2.4
20	Advent International Corp.	2.4	2.4	2.4	2.2	2.4
21	Apax Partners (FKA: Patricof & Co. Ventures, Inc.)	2.4	2.2	2.1	2.4	2.4
22	InterWest Partners	2.7	2.8	2.7	2.4	2.3
23	RS Investments (AKA: Robertson Stephens & Company, LLC)	2.0	2.2	2.2	2.2	2.2
24	Menlo Ventures	2.5	2.4	2.3	2.3	2.1
25	Integral Capital Partners	0.9	1.2	1.3	1.9	2.1
26	Canaan Partners	1.1	1.0	1.1	1.4	1.8
27	Vulcan, Inc.	0.2	0.3	0.8	1.6	1.7
28	Brentwood Venture Capital	1.2	1.3	1.4	1.7	1.7
29	Battery Ventures	1.2	1.3	1.4	1.7	1.7
30	Mohr, Davidow Ventures	1.4	1.4	1.4	1.6	1.7
	Other types of venture capital investors					
1	J.P. Morgan Partners + Chase Capital Partners (inv. bank / affiliate)	4.5	5.3	5.4	6.5	7.9
2	Sprout Group (investment bank / affiliate)	2.9	3.0	2.9	2.6	2.9
3	Goldman, Sachs & Co. (investment bank / affiliate)	1.0	1.6	1.6	2.1	2.8
4	Norwest Venture Partners (subsidiary of other financial institution)	1.5	1.7	1.7	2.3	2.5
5	Intel Capital (corporation)	0.0	0.1	0.4	1.9	2.5

4 RESULTS

4.1 Hedonic analysis

Table 4 presents the results of the hedonic regression analysis of the pre-money valuations. We use the Heckman sample selection approach with maximum-likelihood parameter estimates and White's (1980) correction for heteroskedasticity in a log-log framework, where we regress the logarithm of the pre-money valuation on the dummy variables and the logarithms of the continuous, positive variables.

We explicitly show the effect of five different investor prominence measures for both the current round's new investors and those of the previous round. These measures include the sum, the average, and the maximum of the cumulative IPO market shares of the investors, the sum of the investors' number of prior portfolio companies, and the average firm age of the investors. We also run the regressions using the maximum age of the round's investors, as well as the average and maximum of the number of prior portfolio companies as prominence measures. These unreported models provide results in support of our hypotheses.

The results consistently support the certification hypothesis. With any measure of prominence of existing inside venture capitalists, the effect of prominence on the current round valuation is positive, as expected. New outside investors recognise the certification by prominent inside venture capitalists, and are willing to pay more for their investments than in the absence of such insiders. Prominent insiders increase outsiders' confidence regarding the quality of the venture by putting their reputation at stake. Expectedly, the IPO market share measures have the highest significance levels of the alternative prominence measures. While age, for example, is a good proxy for experience and prominence, it does not as such measure the experience, performance, or status of any single venture capital firm.

Similarly, and with any measure for the prominence of the new outside investors investing in the venture in the current round, prominence is negatively related to the valuation of the financing round. The results indicate that prominent venture capitalists possess and utilise their bargaining power over the valuation of new portfolio companies, and that existing shareholders are willing to issue shares to these investors at lower prices than to less prominent ones. Consistent with the certification hypothesis, the expected benefits from certification by the current round investors in future share issues are taken into account in the valuation of the current round.

Several control variables are significant. Firstly, large financing rounds are valued significantly higher than smaller ones. Although we analyse pre-money valuations that should not be directly dependent on the amount of financing provided, this finding is expected. The amount of financing is supposedly a good measure of firm size, and large firms generally have larger market capitalisations than small ones. The amount of financing provided in the round may also mediate the effect of fund inflows that have been observed to inflate venture capital valuations (Gompers and Lerner, 2000). In periods of high fundraising, venture capital valuations tend to go up because venture funds have more cash to invest in a limited set of ventures. This results in larger capital injections and thus inflated venture valuations.

A second observation is that old ventures are valued higher than young ventures. Mature age is likely to be a proxy for better future prospects and less risk. For similar reasons, the valuations of early-stage ventures are below average, whereas the valuations of later-stage firms are above average. Early-stage ventures have significantly more uncertainty

regarding their ultimate success than later-stage firms. Thirdly, we find that ventures located in California or in one of the three east-coast states with the highest venture capital activity (MA, NJ, NY) have higher valuations than other ventures. The difference is particularly notable in California. Fourthly, certain industries are associated with significantly higher valuations than others. Communications / media, Internet specific, medical / health, semiconductor, and computer hardware industries appear to have higher valuations than others.

Finally, and consistent with Gompers and Lerner (2000), we find that public market valuations and venture capital fund inflows are positively associated with venture valuations. We are, however, unable to test their effect simultaneously because of the high correlation between the two measures. Instead, we enter the variables into the regression models separately. Both of them are found to be significantly and positively related to the pre-money valuations of the financing rounds.

We also include indicator variables for the sample years in the analysis but do not show the coefficients in the tables because of limited space. The boom years 1999 and 2000 appear significantly different from others throughout the models, but the removal or inclusion of the year dummies do not significantly alter the results.

4.2 Analysis of first differences

While the hedonic approach is useful in the sense that it can incorporate firms with only one valuation observation, it cannot take into account all the firm-specific determinants of valuations. To address this concern, we construct a first differences framework for the analysis of valuation changes between rounds, which reduces the impact of firm-specific effects on the results. Table 5 presents a similar Heckman sample selection framework with maximum likelihood parameter estimates and White correction for heteroskedasticity as the hedonic analysis.

First differences provide a complementary possibility to analyse whether investor prominence affects venture capital valuations. According to the hypotheses, prominent investors may get low entry valuations and they may be able to set up high valuations in follow-up rounds. Thus, the post-investment change in the valuation of the venture between financing rounds t and t+1 should be positively related to the prominence of investors that invest in the venture in round t. Investments by top-end investors should be followed by significant increases in valuation, whereas less aggressive write-ups should follow investments made by less prominent VCs.

Table 4 Hedonic approach: Heckman regressions on certification effect and price of certification

The table presents the coefficients of the second equation of a full maximum likelihood Heckman regression. The dependent variable is the logarithm of the pre-money valuation of the financing round. Year dummies are included in all regressions but are not shown because of limited space. Unstandardised regression coefficients and absolute heteroskedasticity-consistent *z*-statistics are presented. Fundraising and the public market index are collinear, and thus they are entered into the regression equation separately.

	Log of round pre-money valuation: log (V_t)											
Sum of new investors' IPO market share	-.385										-.385	
	(1.94)	*									(1.92)	*
Avg of new investors' IPO market share			-.866									
			(2.91)	**								
Max of new investors' IPO market share					-.598							
					(2.56)	**						
Sum of new investors' cumulative number of portfolio companies (log)							-.070					
							(5.28)	***				
Avg of new investor's firm age (log)									-.105			
									(4.75)	***		
Existing investors' prominence (using the same measure as for new investors)	1.614		1.698		1.999		.067		.058		1.622	
	(11.09)	***	(5.75)	***	(9.22)	***	(4.99)	***	(2.18)	*	(11.09)	***
Total amount of financing (log)	.485		.504		.493		.655		.747		.491	
	(17.93)	***	(19.52)	***	(18.52)	***	(15.13)	***	(24.58)	***	(18.01)	***
Company age (log)	.187		.192		.191		.143		.107		.194	
	(6.64)	***	(6.70)	***	(6.74)	***	(4.44)	***	(3.71)	***	(6.84)	***
Early stage?	-.622		-.644		-.629		-.586		-.521		-.626	
	(12.13)	***	(12.45)	***	(12.26)	***	(9.57)	***	(8.83)	***	(12.18)	***
Later stage?	.238		.257		.246		.218		.219		.237	
	(6.08)	***	(6.49)	***	(6.27)	***	(5.12)	***	(4.98)	***	(6.00)	***
Firm located in California?	.095		.120		.101		.152		.129		.094	
	(2.45)	*	(3.05)	**	(2.60)	**	(3.52)	***	(2.95)	**	(2.40)	*
Firm located in MA, NJ, or NY?	.048		.071		.059		.055		.035		.050	
	(1.00)		(1.45)		(1.22)		(1.05)		(.66)		(1.04)	
Internet specific?	.243		.241		.244		.162		.076		.245	
	(5.43)	***	(5.29)	***	(5.40)	***	(3.18)	***	(1.52)		(5.45)	***
Biotechnology?	-.131		-.090		-.103		-.218		-.292		-.126	
	(1.87)	+	(1.29)		(1.48)		(2.73)	**	(3.67)	***	(1.79)	+
Communications/media?	.231		.271		.251		.239		.187		.230	
	(4.33)	***	(4.98)	***	(4.66)	***	(3.99)	***	(3.15)	**	(4.28)	***
Computer hardware?	-.159		-.147		-.159		-.303		-.304		-.155	
	(1.71)	+	(1.57)		(1.71)	+	(3.17)	**	(3.08)	**	(1.67)	+
Semiconductors?	.236		.243		.241		.131		.093		.228	
	(3.27)	***	(3.28)	***	(3.33)	***	(1.75)	+	(1.16)		(3.18)	***
Consumer related?	.031		.001		.028		.068		.038		.019	
	(.19)		(.00)		(.17)		(.36)		(.20)		(.12)	
Medical/health?	-.324		-.291		-.312		-.260		-.246		-.323	
	(5.03)	***	(4.47)	***	(4.82)	***	(3.49)	***	(3.31)	***	(5.00)	***
Industrial/energy?	.019		-.011		.015		-.179		-.495		.004	
	(.10)		(.06)		(.08)		(.41)		(2.47)	*	(.02)	
Nasdaq Composite index (log)	.406		.391		.409		.273		.129			
	(8.18)	***	(7.92)	***	(8.26)	***	(4.77)	***	(2.57)	**		
Venture capital fundraising (log)											.218	
											(7.17)	***
(year dummies omitted from the table)												
Constant	2.108		2.128		2.010		1.751		2.238		2.850	
	(5.85)	***	(5.91)	***	(5.60)	***	(4.46)	***	(5.24)	***	(9.12)	***
X^2-statistic	2559.2		2474.0		2537.4		2040.2		1747.0		2438.7	
p-value	0.000		0.000		0.000		0.000		0.000		0.000	
N (all 32,311 financing rounds entered in the Heckman equation)	5,652		5,652		5,652		5,357		5,120		5,652	

*** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level; 1-tailed tests for the hypothesised relationships, 2-tailed tests for control variables

Using the same five different investor prominence measures as in the hedonic analysis, we again find consistent support for the certification hypothesis. All the prominence measures are positively and significantly related to the value increase between the current round and the next round. Ventures with prominent venture capitalists experience higher write-ups in value than other ventures. The prominence measures based on IPO market share appear most significant, but investment experience and age variables indicate similar significant results.

Again, several control variables are included the analysis. Most importantly, we explicitly control for the absolute pre-money valuation of the current round. As we have documented that the prominence of the current round investors is negatively related to the valuation of the current round, a larger-than-average increase in valuation after the round might result only from the fact that the valuation was at a low level in the beginning. As expected, higher valuations in the current round result in smaller increases between the current and the next rounds. The removal or inclusion of this control variable does not, however, alter the results.

Consistent with expectations and prior research, later-stage firms appear to experience smaller increases in valuations than other firms. Valuation changes are also smaller for older firms, but the relationship is insignificant. Companies located in California differ from others in terms of higher write-ups. There are clear patterns in the industry of the venture. Firms in communications/media, Internet specific, medical/health, and semiconductor industries appear to experience higher valuation increases than others.

Several variables measuring developments between the two financing rounds are significant. Firstly, the longer the interval between the two financing rounds, the larger the increase in valuation. Progress to a higher stage of development also implies a significant improvement in valuation. Such progress substantially increases the likelihood that the investment will ultimately be successful. Finally, changes in the public market index are strongly and positively correlated with changes in venture capital valuations, but the coefficient of change in fundraising does not seem to be significant. Although the public market index and the level of fundraising were previously found to be highly correlated, the inclusion of the first differences of these indices in the same regression models does not lead to multicollinearity problems.

Indicator variables for the sample years are also included in this analysis even though space does not allow us to present the coefficients. Significantly higher valuation increases are associated with the later sample years, and significantly smaller increases with the early years. However, the inclusion or removal of the year dummies does not alter the results.

Table 5 First differences analysis: Heckman regressions on certification effect

The table presents the coefficients of the second equation of a full maximum likelihood Heckman regression. Unstandardised regression coefficients and absolute heteroskedasticity-consistent *z*-statistics are presented. *** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level; 1-tailed tests for the hypothesised relationships, 2-tailed tests for controls

	Log change in round pre-money valuation: $\log(V_{t+1}) - \log(V_t)$									
Sum of investors' IPO market share, *t*	1.540									
	(8.31)	***								
Avg of investors' IPO market share, *t*			1.877							
			(7.16)	***						
Max of investors' IPO market share, *t*					1.682					
					(7.81)	***				
Sum of investors' cumulative number of portfolio companies (log) , *t*							.068			
							(5.81)	***		
Avg of investor's firm age (log), *t*									.046	
									(1.84)	*
Round valuation (log), *t*	-.358		-.356		-.357		-.370		-.365	
	(13.22)	***	(13.15)	***	(13.17)	***	(11.81)	***	(10.66)	***
Company age (log), *t*	-.008		-.013		-.009		.008		-.013	
	(.31)		(.51)		(.36)		(.28)		(.42)	
Early stage?	.053		.054		.053		.027		.065	
	(.79)		(.81)		(.80)		(.33)		(.75)	
Later stage?	-.428		-.438		-.432		-.468		-.496	
	(4.62)	***	(4.75)	***	(4.68)	***	(4.07)	***	(4.26)	***
Firm located in California?	.166		.175		.169		.182		.260	
	(3.23)	***	(3.39)	***	(3.29)	***	(3.02)	***	(3.99)	***
Firm located in MA, NJ, or NY?	.039		.048		.045		.022		.096	
	(.69)		(.83)		(.79)		(.34)		(1.36)	+
Internet specific?	.357		.373		.361		.329		.356	
	(4.53)	***	(4.76)	***	(4.61)	***	(3.86)	***	(4.18)	***
Biotechnology?	.071		.088		.078		.038		.083	
	(.85)		(1.06)		(.94)		(.40)		(.82)	
Communications/media?	.376		.393		.382		.397		.430	
	(5.08)	***	(5.28)	***	(5.14)	***	(4.81)	***	(4.89)	***
Computer hardware?	-.003		.011		-.005		-.037		-.019	
	(.02)		(.08)		(.04)		(.26)		(.13)	
Semiconductors?	.158		.174		.160		.116		.183	
	(1.71)	*	(1.85)	*	(1.72)	*	(1.09)		(1.63)	+
Consumer related?	-.243		-.241		-.243		-.100		-.102	
	(1.17)		(1.16)		(1.17)		(.41)		(.41)	
Medical/health?	-.314		-.312		-.316		-.374		-.387	
	(4.54)	***	(4.47)	***	(4.55)	***	(4.61)	***	(4.37)	***
Industrial/energy?	-.442		-.458		-.443		-.703		-.741	
	(2.95)	**	(3.00)	**	(2.92)	**	(3.26)	***	(3.24)	***
Change in total amount of financing (log)	.081		.072		.078		.113		.111	
	(4.02)	***	(3.61)	***	(3.87)	***	(4.42)	***	(3.95)	***
Time between rounds (log)	.097		.102		.099		.031		.036	
	(2.66)	**	(2.79)	**	(2.70)	**	(.75)		(.79)	
Progress from early stage?	.389		.395		.391		.393		.475	
	(4.14)	***	(4.24)	***	(4.18)	***	(3.72)	***	(4.44)	***
Progress from expansion stage?	.668		.685		.675		.697		.776	
	(5.19)	***	(5.36)	***	(5.26)	***	(4.59)	***	(5.11)	***
Change in Nasdaq Composite index (log)	.274		.267		.270		.447		.431	
	(2.76)	**	(2.65)	**	(2.71)	**	(3.98)	***	(3.60)	***
Change in VC fundraising (log)	.029		.030		.029		.001		-.003	
	(.35)		(.36)		(.35)		(.01)		(.03)	
(Year dummies omitted from the table)										
Constant	2.083		2.031		2.068		1.925		1.735	
	(3.69)	***	(3.63)	***	(3.67)	***	(2.85)	**	(2.60)	**
X^2-statistic	653.9		634.9		646.1		525.2		441.5	
p-value	0.000		0.000		0.000		0.000		0.000	
N (all 32,311 financing rounds entered in the Heckman equation)	1,921		1,921		1,921		1,765		1,697	

4.3 Further robustness checks and alternative explanations

Certification versus selection of inherently better ventures. One typical concern in research that examines the value adding influences of venture capitalists is the challenge of separating the value-adding effects from the "cherry picking ", i.e., the selection of ventures that will be successful. According to selection logic, the ventures could gain above-average market valuations even without investor certification or value-adding capabilities, and the association between investor prominence and future valuation increases could merely result from the investors' selecting ability rather than certification. However, our research design should alleviate the problem of such reverse causality. There are two important features in our research design that help us deal with this problem.

Firstly, our hypotheses posit that prominence first reduces the valuation when a prominent investor makes the investment (bargaining power) but increases the valuation in subsequent rounds (certification) when controlling for other factors. If prominent investors were superior in selecting above-average ventures but did not have certifying abilities, we would not observe that they pay less for their investments when they enter the venture as new investors. There should be no reason why entrepreneurs let prominent investors push down valuations if they could not provide certification or value-adding resources. Because these bargaining power and certification effects are tested in the same analytical models, the results could hardly be explained by selection.

Secondly, we employ panel data consisting of several observations per venture. This makes it possible for us to track the value creation rates of new ventures and to relate the investor prominence to the changes in value creation rates. To ensure that our sample supports the certification hypothesis, we examined how investor prominence affected the rate of change in pre-money market value at the time of the financing round. If investors added value through certification or other mechanisms, investor prominence would be positively related to the change in the rate of market value creation, because these investors could 'push' the valuation down when entering the venture and 'pull' it up in subsequent rounds when new investors enter. On the other hand, if investors merely select inherently better ventures, their prominence would not change the rate of market value creation at the time they enter the venture as new investors. 'Cherry picking' would be likely to appear as a higher than average valuation even at the time of the initial investment.

Consider a venture that had three financing rounds at times t_1, t_2, and t_3, the pre-money valuations of which were V_1, V_2, and V_3. Then the rate of creating market value would be $r_{12} = (V_2 - V_1)/(t_2 - t_1)$ between rounds 1 and 2 and $r_{23} = (V_3 - V_2)/(t_3 - t_2)$ between round 2 and 3. The change in the rate of market value creation would be the ratio r_{23}/r_{12}. We expect investor prominence to be positively related to this ratio and run a maximum-likelihood Heckman regression with a similar log-log framework and control variables as previously to verify the argument.

This robustness test resulted in further support for our hypotheses. The results, presented in Table 6, demonstrate that investor prominence is associated with a positive change in the rate of value increase. New investments by prominent investors significantly boost the rate of adding value between financing rounds. In the regressions, we employ the same additional control variables as in Table 5.

Table 6 Ensuring intra-firm consistency of results: Heckman regressions

The table presents the coefficients of the second equation of a full maximum likelihood Heckman regression. The dependent variable is the logarithmic change in the rate of adding pre-money market value at the time of the financing round, defined as Log(r_{23}/r_{12}), where $r_{12} = (V_2 - V_1)/(t_2 - t_1)$ and $r_{23} = (V_3 - V_2)/(t_3 - t_2)$, V denoting venture valuation and t the timing of a financing round. The same control variables as in Table 5 are included but not shown because of limited space. Unstandardised regression coefficients and absolute heteroskedasticity-consistent z-statistics are presented.

	Change in rate of adding pre-money market value: log (r_{23}/r_{12})					
Sum of investors' IPO market share	1.854					
	(3.24)	***				
Sum of investors' cumulative number of portfolio companies (log), t			.121			
			(3.08)	***		
Avg of investor's firm age (log), t					.136	
					(1.95)	*
$t_2 - t_1$	1.079		.936		.857	
	(7.28)	***	(5.72)	***	(5.26)	***
$t_3 - t_2$	-.915		-.995		-.962	
	(10.06)	***	(6.42)	***	(6.14)	***
(other control variables and year dummies omitted from the table)						
Constant	11.223		11.056		10.057	
	(7.06)	***	(5.60)	***	(4.57)	***
X-statistic	266.6		265.7		265.6	
p-value	0.000		0.000		0.000	
N (all 32,311 financing rounds entered in the Heckman equation)	753		728		695	

*** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level;1-tailed tests for the hypothesised relationships, 2-tailed tests for control variables

Certification versus other value-adding mechanisms. Another challenge is to distinguish between prominence-related certification effects that are in the focus of the present analysis, and other potential value-adding activities of venture capitalists.

Previous research indicates that venture capitalists play a significantly more active role in managing their investments than traditional financial intermediaries. After the initial investment, venture capitalists engage in several 'value-adding' activities with their portfolio companies. These activities include monitoring financial and operational performance, recruitment of management, arranging financing from complementary sources, serving as a sounding broad to entrepreneur team, arranging incentive plans, providing access to auditors, lawyers, and investment banks, and setting company policies (MacMillan *et al.*, 1988; Gorman and Sahlman, 1989; Rosenstein *et al.*, 1993; Sapienza, 1992; Sapienza *et al.*, 1996; Hellmann and Puri, 2000; 2002). Management literature stresses that prominent firms may be able to attract greater and higher-quality resources than other firms. If the VC firm provides access to its resources for its portfolio companies, they may be able to gain a competitive advantage (Stuart *et al.*, 1999). New

ventures might be willing to pay for such benefits, which might increase the bargaining power of prominent investors over the valuation of the venture. Thus, the relationship between venture valuation and investor prominence observed in our analyses might be a result of resource provision rather than certification. There are two main methods we used to ensure the consistency of our prominence-related certification and bargaining power hypotheses in the presence of other potential mechanisms influencing value creation.

Firstly, previous research suggests that it is possible to obtain firm support for the certification hypothesis by examining whether the certification effect we claim to have found is contingent on the degree of uncertainty about the quality of the venture (Stuart *et al*., 1999; Stuart, 2000). Outside investors are more eager to put particular emphasis on the prominence of existing investors and other organisations associated with the focal venture when they do not have sufficient information about the venture to reach an independent judgement about its future prospects. As a result, the prominence of existing investors should have a strong effect on the assessments of the value of a venture when uncertainty about the venture's quality is high. On the other hand, when outside investors are confident of their ability to assess the quality of a venture, there is little need to infer the quality of the company on the basis of the identity and prominence of existing investors in the venture, which results in a smaller impact of the existing investors' prominence on the value of the focal company. Such contingency of certification on uncertainty is emphasised in both the signalling literature and later studies on interorganisational endorsements (Spence, 1974; Stuart *et al*., 1999).

The same contingency argument applies to the bargaining power of new investors over the valuation of the venture. When uncertainty about the quality of the venture is high, the expected value of certification to existing shareholders is similarly high because the prominence of new investors helps to resolve informational asymmetries in future financings. As a result, the prominence of new investors should have a stronger effect on the valuation of the venture when uncertainty is high. On the other hand, when uncertainty about the venture's quality is low, the expected value of certification is similarly low because future investors can independently evaluate the venture reasonably well. Thus, the prominence of new investors should have less impact on the valuation of the venture.

The contingency on uncertainty allows us to test the certification hypothesis using interactions between prominence and uncertainty variables. We measured uncertainty using two variables, age and an indicator variable of the number of prior financing rounds. Firstly, venture age is a good proxy for uncertainty because young companies have limited performance histories on the basis of which quality could be assessed (Sahlman, 1990). Furthermore, venture capitalists are reluctant to invest large sums of money in young companies, and typically stage their early-stage investments in smaller injections contingent on performance (Sahlman, 1990; Gompers, 1995). The

institutionalisation of staged financing in venture capital is in itself strong support for the argument that the degree of uncertainty about a venture declines as it ages (Stuart *et al.*, 1999). Secondly, the number of prior financing rounds is closely related to the uncertainty of the venture because ventures undergo a thorough evaluation by venture capitalists when they raise financing. All these evaluations convey information of the quality of the venture to outside investors at least through the venture capitalists' decisions to invest or not to invest. Share issues also, in general, result in some sort of documentation of the firm's activities prior to the issue, and investors participating in later financing rounds generally have an opportunity to examine the documents of prior financing rounds during their own due diligence process. As a result, later-round investors have a significantly broader range of information about the venture in their use than first-round investors.

The results of the Heckman regressions with interaction terms included are reported in Table 7. The dependent variable is the logarithm of the pre-money valuation of the financing round. We first interact investor prominence with age and then with an indicator variable that is assigned the value of one if the venture has undergone three or more prior financing rounds. The models include the same control variables and year dummies as in Table 4. In order to conserve space, we report only the relevant coefficients. In both of the models, the coefficient of the interaction variable between uncertainty and existing investors' prominence is negative, which implies that the impact of existing investors' prominence on company valuation declines with the age of the venture and the number of financing rounds it has undergone. Older ventures that have longer operating histories gain less from certification by prominent investors, while new ventures gain proportionally more. Similarly, new investors have less bargaining power over the valuation of less uncertain ventures. This is reflected in the negative coefficient of the interaction variable between uncertainty and the prominence of new investors. While new, prominent investors can negotiate large discounts to the valuation of uncertain ventures, their ability to do so in the case of more established ventures is much weaker. Relative valuations are higher in the case of more established ventures because the expected value of investor certification is smaller than in the case of new, uncertain ventures.

We also test the effect of defining the indicator variable as two or more rounds or four or more rounds prior to the current financing round, and find similar results to those reported here. Similarly, the results are robust to the different measures of investor prominence.

Table 7 Adding interaction terms to the base Heckman regressions

The table presents the coefficients of the second equation of a full maximum likelihood Heckman regression. The dependent variable is the logarithm of the pre-money valuation of the financing round. The same control variables as in 4 are included but not shown because of limited space. Unstandardised regression coefficients and absolute heteroskedasticity-consistent *z*-statistics are presented.

	Log of round pre-money valuation: log (V_t)					
Sum of existing investors' IPO market share	1.614		2.363		1.572	
	(11.09)	***	(7.45)	***	(7.80)	***
Sum of new investors' IPO market share	-.385		-.173		-.117	
	(1.94)	*	(.50)		(.49)	
Log of company age * Sum of existing investors' IPO market share			-.599			
			(2.67)	**		
Log of company age * Sum of new investors' IPO market share			-.502			
			(2.08)	*		
Company had previously 3 or more financing rounds * Sum of existing investors' IPO market share					-.510	
					(1.64)	*
Company had previously 3 or more financing rounds * Sum of new investors' IPO market share					-.568	
					(1.67)	*
Log of company age	.187		.318		.149	
	(6.64)	***	(5.75)	***	(5.05)	***
Company had previously 3 or more financing rounds					.287	
					(3.82)	***
(other control variables and year dummies omitted from the table)						
Constant	2.108		1.911		1.919	
	(5.85)	***	(5.50)	***	(5.25)	***
X^2-statistic	2559.2		2569.5		2653.9	
p-value	0.000		0.000		0.000	
N (all 32,311 financing rounds entered in the Heckman equation)	5,652		5,652		5,652	

*** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level; 1-tailed tests for the hypothesised relationships, 2-tailed tests for control variables

Our results provide support for the certification hypothesis. While we fully agree that prominent venture capitalists may also be superior in providing value-adding resources to their portfolio companies, the results on the contingency of certification on uncertainty show that venture capitalist prominence is associated with their ability to certify the quality of new ventures. The greater the uncertainty regarding the quality of the venture, the more outside investors rely on the prominence of existing investors, and the more outside investors can utilise their prominence as a source of bargaining power over the valuation of the venture. Although the findings document the relationship between investor prominence and certification, we would like to stress that certification and the provision of superior value-adding resources are not mutually exclusive explanations of the effect of investor prominence on the value of new ventures. Rather, we would expect these explanations to be complementary. However, the lack of applicable data prevents us from directly testing the relationship between prominence and the provision of value-adding resources.

Period of the study. One obvious concern is whether the period of the sample affects the results. Although our sample covers an 11-year period of venture capital investments, and thus covers both upturns and downturns in the industry, the majority of our valuation observations are concentrated in the boom years of 1999 and 2000. The

extraordinarily large private company valuations and associated valuation increases in these years (Table 1) might distort the results in spite of our dummy variables controlling for the different sample years in the regressions. To address this concern, we ran the regressions using different sampling periods. We employed data from 1990 – 1994, 1993 – 1997, 1996 – 2000, and 1999 – 2000. All these sub-samples provided qualitatively similar results, and the prominence variables remained significant in all cases. Thus, the sampling period does not appear to affect our findings.

5 DISCUSSION AND CONCLUSIONS

This paper set out to examine the effect of venture capitalist prominence on the valuations of privately held companies. Contributing to the literature on asymmetric information and signalling theories, we have extended previous research on certification in financial markets. Adding to the previous certification literature, we developed and tested two hypotheses derived from the certification framework. Firstly, we hypothesised and demonstrated that prominence gives venture capitalists bargaining power and allows them to invest at lower valuations when controlling for other factors. Secondly, we hypothesised and demonstrated that certification by prominent venture capital investors reduces the discount resulting from informational asymmetries and thus leads to increased valuations in subsequent investment rounds. The results are controlled for various selection biases and are robust to alternative explanations.

The implications of this paper have theoretical significance in many ways. Our results extend previous evidence regarding certification by financial intermediaries from the context of initial public offerings and public markets to the context of privately held companies. While previous research has shown that venture capitalists can certify the price of initial public offerings, this paper shows that certification significantly affects valuations already in the private financing stages in two ways. Firstly, the cost of credible signalling to the venture is realised in terms of lower entry valuations for prominent venture capitalists. Secondly, outside investors recognise the value of certification and are willing to pay higher valuations in follow-up rounds if prominent investors have invested in the venture.

The explanation for these observations is the certification effect. The results show that the impact of prominence on company valuations is contingent on uncertainty. While tangible value-adding capabilities could otherwise explain our findings and outweigh the certification effect, contingency on uncertainty affirms that at least the certification effect exists. Our results thus provide support for certification and signalling theories, but do not argue in favour of or against theories on the tangible value-adding capabilities of venture capital investors. Furthermore, the methodology of the paper also provides an approach for measuring the prominence or reputation of venture capitalists. IPO market share is a consistent measure of prominence, being strongly correlated with investment experience and slightly less strongly with the age of the venture capital firm.

Our paper additionally provides several practical implications. The results imply that informational asymmetries are a significant factor affecting investment decision-making in venture capital. New investors always confront quality uncertainty when evaluating prospective new portfolio companies. While insider entrepreneurs are less likely to be able to signal the true quality of their venture in a credible way, prominent venture capitalists that are repeatedly present in the investment and exit markets are able to provide certificates of quality. By putting their reputation at stake and investing in a new venture, prominent venture capitalists can reduce informational asymmetries between the venture and other outside investors in follow-up financing rounds. As a result, prominent venture capitalists reduce the cost of follow-up financings. Our paper further suggests that investor prominence can and will be leveraged in valuation negotiations with entrepreneurs.

The main limitations of this paper arise from the fact that it is a great challenge to fully control for unobserved effects that might affect the valuations we analyse in this paper. Even though our use of several control variables and the first differences approach significantly reduce this potential problem, it is not possible to totally alleviate unobserved heterogeneity. A possible alternative approach would be to take the financing offer as the unit of analysis and compare the valuations that different VCs placed on the same venture at the same time (Hsu, 2002). While this method would allow to hold the characteristics of the venture fixed, it would require administering a survey, giving up a vast amount of data points, and limiting the sample to ventures that received multiple offers for the same financing round. Furthermore, there would still be potential unobserved heterogeneity between the different offers the startups received. While we believe that such an analysis could complement the methodology employed in this paper, we feel that our empirical models demonstrate an adequate level of rigor to ensure the robustness of the results.

In addition to the need for validation of the results in other geographical markets and in the case of buyouts, this paper provides an interesting path for future research on venture capital syndications. Does prominence provide venture capitalists with negotiation power over their syndicate partners, and do venture capitalists utilise it in practice? While the nominal valuation of a syndicated investment round is typically the same for all participants irrespective of status, prominent venture capitalists may seek additional benefits by structuring the deal in favour of themselves. Further research on contracting in venture capital syndications could shed light on the impact of prominence on the co-operation between venture capitalists.

REFERENCES

Admati AR, Pfleider P. 1994. Robust financial contracting and the role of venture capitalists. *Journal of Finance* 49(2): 371 – 402.

Akerlof G. 1970. The Market for Lemons: Quality Uncertainty and the Market Mechanism. *Quarterly Journal of Economics* 84(3): 488 – 500.

Aldrich H, Auster ER. 1986. Even Dwarfs Started Small: Liabilities of Age and Size and Their Strategic Implications. In Cummings LL, Staw BM. Ed. *Research in Organizational Behavior*. JAI Press: Greenwich, CT.

Barry CB, Muscarella CJ, Peavy JW, Vetsuypens MR. 1990. The Role of Venture Capital in the Creation of Public Companies. *Journal of Financial Economics* 27(2): 447 – 471.

Beatty RP. 1989. Auditor Reputation and the Pricing of Initial Public Offerings. *The Accounting Review* 64(4): 693 – 709.

Beatty RP, Ritter JR. 1986. Investment Banking, Reputation, and the Underpricing of Initial Public Offerings. *Journal of Financial Economics* 15: 213 – 232.

Beatty RP, Welch I. 1996. Issuer Expenses and Legal Liability in Initial Public Offerings. *Journal of Law and Economics* 39: 545 – 602.

Benjamin BA, Podolny JM. 1999. Status, Quality, and Social Order in the California Wine Industry. *Administrative Science Quarterly* 44: 563 – 589.

Booth J, Smith R. 1986. Capital Raising, Underwriting, and the Certification Hypothesis. *Journal of Financial Economics* 15(1/2): 261 – 281.

Bygrave WD. 1989. Early Rates of Return of 131 Venture Capital Funds Started 1978-1984. *Journal of Business Venturing* 4(2): 93 – 105.

Bygrave WD, Timmons JA. 1992. *Venture Capital at the Crossroads*. Harvard Business School Press: Boston, MA.

Carter RB, Manaster S. 1990. Initial Public Offerings and Underwriter Reputation. *Journal of Finance* 45(4): 1045 – 1067.

Carter RB, Dark FH, Singh A. 1998. Underwriter Reputation, Initial Returns, and the Long-Run Performance of IPO Stocks. *Journal of Finance* 53(1): 285 – 311.

Chemmanur TJ, Fulghieri P. 1994. Investment Bank Reputation, Information Production, and Financial Intermediation. *Journal of Finance* 49(1): 57 – 79.

Fama E, French K. 1992. The Cross-Section of Expected Stock Returns. *Journal of Finance* 47(2): 427 – 465.

Gompers PA. 1995. Optimal Investment, Monitoring, and the Staging of Venture Capital. *Journal of Finance* 50(5): 1461 – 1489.

Gompers PA. 1996. Grandstanding in the Venture Capital Industry. *Journal of Financial Economics* 42(1): 133 – 156.

Gompers PA, Lerner J. 1999. *The Venture Capital Cycle.* The MIT Press: Cambridge, MA.

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

Gorman M, Sahlman WA. 1989. What Do Venture Capitalists Do? *Journal of Business Venturing* 4(4): 231 – 248.

Heckman JJ. 1979. Sample Selection Bias as a Specification Error. *Econometrica* 45: 53 – 161.

Hellmann T. 1998. The Allocation of Control Rights in Venture Capital Contracts. *Rand Journal of Economics* 29: 57 – 76.

Hellmann T, Puri M. 2000. The Interaction between Product Market and Financing Strategy: The Role of Venture Capital. *Review of Financial Studies* 13(4): 959 – 984.

Hellmann T, Puri M. 2002. Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence. *Journal of Finance* 57(1): 169 – 197.

Hsu D. 2002. *What Do Entrepreneurs Pay for Venture Capital Affiliation?* Working paper, University of Pennsylvania.

Jensen MC. 1986. Agency Costs of Free Cash Flow, Corporate Finance, and Takeovers. *American Economic Review* 76(2): 323 – 329.

Kirilenko AA. 2001 Valuation and Control in Venture Finance. *Journal of Finance* 56(2): 565 – 587.

Kortum S, Lerner J. 2000. Assessing the Contribution of Venture Capital to Innovation. *RAND Journal of Economics* 31(4): 674 – 692.

Lerner J. 1994. The Syndication of Venture Capital Investments. *Financial Management* 23(3): 16 – 27.

Lerner J. 1995. Venture Capitalists and the Oversight of Private Firms. *Journal of Finance* 50(1): 301 – 318.

Livingston M, Miller RE. 2000. Investment Bank Reputation and the Underwriting of Nonconvertible Debt. *Financial Management* 29(2): 21 – 34.

MacMillan IC, Kulow DM, Khoylian R. 1988. Venture Capitalists' Involvement in Their Investments: Extent and Performance. *Journal of Business Venturing* 4(1): 27 – 47.

Megginson WL, Weiss KA. 1991. Venture Capitalist Certification in Initial Public Offerings. *Journal of Finance* 46(3): 879 – 903.

Michaely R, Shaw WH. 1995. Does the Choice of Auditor Convey Quality in an Initial Public Offering? *Financial Management* 24(4): 15 – 30.

Podolny JM. 1993. A Status-Based Model of Market Competition. *American Journal of Sociology* 98: 829 – 872.

Podolny JM. 2001. Networks as Pipes and Prisms of the Market. *American Journal of Sociology* 107(1): 33 – 60.

Rosenstein JA, Bruno V, Bygrave WD, Taylor NT. 1993. The CEO, Venture Capitalists, and the Board. *Journal of Business Venturing* 8(2): 99 – 113.

Ruhnka JC, Young JE. 1991. Some Hypotheses about Risk in Venture Capital Investing. *Journal of Business Venturing* 6(2): 115 – 133.

Sahlman WA. 1990. The Structure and Governance of Venture-Capital Organizations. *Journal of Financial Economics* 27: 473 – 521.

Sapienza HJ. 1992. When Do Venture Capitalists Add Value? *Journal of Business Venturing* 7(1): 9 – 27.

Sapienza HJ, Manigart S, Vermeir W. 1996. Venture Capitalist Governance and Value-added in Four Countries. *Journal of Business Venturing* 11(6): 439 – 469.

Seppä TJ, Laamanen T. 2001. Valuation of Venture Capital Investments: Empirical Evidence. *R&D Management* 31(2): 215 – 230.

Spence AM. 1974. *Market Signaling: Informational Transfer in Hiring and Related Screening Processes*. Harvard University Press: Cambridge, MA.

Stinchcombe AL. 1965. Social Structure and Organizations. In March J. Ed. *Handbook of Organizations*. Rand McNally: Chicago, IL.

Stuart TE. 2000. Interorganizational Alliances and the Performance of Firms: A Study of Growth and Innovation Rates in a High-Technology Industry. *Strategic Management Journal* 21: 791 – 811.

Stuart TE, Hoang H, Hybels R. 1999. Interorganizational Endorsements and the Performance of Entrepreneurial Ventures. *Administrative Science Quarterly* 44(2): 315 – 349.

Waugh FW. 1928. Quality Factors Influencing Vegetable Prices. *Journal of Farm Economics* 10(2): 185 – 196.

Wetzel WE. 1981. Informal Risk Capital in New England. In Vesper KH. Ed. *Frontiers of Entrepreneurship Research*. Babson College: Wellesley, MA.

White H. 1980. A Heteroskedasticity-Consistent Covariance Matrix Estimator and a Direct Test for Heteroskedasticity. *Econometrica* 48: 817 – 838.

ESSAY 3:

SYNDICATION AND THE EFFICIENCY OF VENTURE CAPITAL FIRMS

Abstract. This paper examines the relationship between investment syndication and the efficiency of venture capital firms. Arguments derived from the theoretical motives for syndication predict that syndication relationships allow venture capitalists to be more efficient in completing investments and in making their portfolio companies public. Utilising an extensive data set comprising the venture capital investments of the 100 largest U.S. venture capital firms between 1986 and 2000, this paper demonstrates that syndication has an impact on venture capitalists' efficiency in both of these areas. The frequency of syndicating investments accelerates the process of investing in new portfolio companies, whereas the diversity of the syndication relationships improves the venture capitalists' ability to create public companies from their portfolio companies. Furthermore, we find that uncertainty moderates the impact of syndication on firm efficiency. Firms with more uncertain venture portfolios benefit more from engaging in syndication relationships.

1 INTRODUCTION

Previous researchers have identified several reasons to explain why venture capitalists frequently syndicate their investments, or co-invest in the same portfolio companies. Empirical studies have demonstrated that venture capitalists form tightly coupled syndication networks (Bygrave, 1987; 1988, Sorenson and Stuart, 2001), and that syndication relationships are often repetitive and reciprocal (Bygrave, 1987; 1988; Lerner, 1994; Sorenson and Stuart, 2001). While the debate on the motives for syndication is still on-going, the most common suggestions cover improved capabilities to add value to the portfolio companies (Bygrave, 1987; Brander *et al*., 1999), spreading financial value at risk (Sahlman, 1990; Lerner, 1994; Lockett and Wright, 2001), improved investment decision-making (Wilson, 1968; Lerner, 1994), information sharing on new, potential deals (Bygrave, 1987), social structural reasons such as establishment of status (Podolny, 2001), and window dressing (Lerner, 1994).

While previous research has extensively examined the reasons for establishing syndication relationships, significantly fewer insights are offered about the impact of syndication on the venture capital firm and its ability to generate returns on its investments. Rational venture capitalists seek to establish syndicates when the expected benefits from forming a syndicate exceed the cost of splitting up the investment and potential future returns. Syndication relationships may, indeed, have effects that improve the focal firm's ability to generate high returns on investment, but they may also have an adverse impact on the firm. For example, engaging several venture capitalists in the board of a portfolio company may provide complementary value-adding capabilities to the portfolio company, but may also give incentives for any single venture capitalist to 'free ride' after the initial investment and expect other VCs to add value. Similarly, reciprocal sharing of information on new deals with previous syndication partners may be necessary to keep up the future deal flow of the focal venture capital firm, but may also dilute the potential competitive advantage the focal firm may gain from deal information it kept to itself. Furthermore, engaging several parties in investment decision-making tends to make the process of arriving at the final decision much slower and more cumbersome than if the firm acted on its own, even though joint decision-making may lead to better investment decisions (Wilson, 1968) and improve the probability that the investment will in fact be successful.

To provoke a structured discussion on the benefits and drawbacks of venture capital syndication, this paper sets out to examine if and how syndication relationships affect the efficiency of venture investors. Firstly, we establish an empirical relationship between the frequency of syndication, the diversity of syndication relationships, and the efficiency of venture capital firms. Secondly, we examine how uncertainty affects the potential impact of syndication on firm efficiency. We utilise an extensive data set of over 50,000 venture capital investments made in the U.S. between 1986 and 2000, construct a longitudinal set

of syndication measures, and supplement the data set with longitudinal data on the venture capital firms and the initial public offerings of their portfolio companies.

The paper is organised as follows. Section 2 builds the testable hypotheses. Section 3 presents the data and the methods used. Section 4 presents the empirical results. Finally, conclusions and implications are discussed in section 5.

2 THEORY AND HYPOTHESES

2.1 Rationales for syndication

Previous studies have discussed and elaborated the motivations for syndication among venture capitalists (Bygrave, 1987; Bygrave, 1988; Lerner, 1994; Brander *et al*., 1999; Lockett and Wright, 2001). Six main groups of rationales for syndication have been identified.

Improved capabilities to add value. The sharing of expertise and 'value-adding' resources and capabilities may motivate venture capital firms to co-invest (Bygrave, 1987; Brander *et al*., 1999). The potential value-adding activities of a venture capitalist include, for example, monitoring financial and operational performance, recruitment of management, arranging financing from complementary sources, serving as a sounding board to the entrepreneurial team, arranging incentive plans, providing access to auditors, lawyers, and investment banks, and setting company policies (MacMillan *et al*., 1988; Gorman and Sahlman, 1989; Rosenstein *et al*., 1993; Sapienza, 1992; Sapienza *et al*., 1996; Hellman and Puri, 2000; 2002). Thus, venture capitalists have a much more active role in managing their investments than public market investors. Through the value-adding activities, venture capitalists can influence both the expected return and the risk of their investments.

The 'value-added' motive for syndication is essentially based on resource-based arguments and resource complementarities. From the resource-based perspective, syndication relationships allow the venture capitalist to add value to the investments without the need to accumulate specialised resources for a long time (Ahuja, 2000). Syndication relationships allow the focal venture firm to benefit from the valuable, firm-specific, imperfectly imitable, and non-substitutable resources the syndicate partners use to add value to the shared portfolio company. Venture capitalists tend to have heterogeneous skills and information, and can add value to the target firm in complementary ways after the investment. They also have complementary networks of relationships to corporations, investment banks, lawyers, and potential senior managers for the portfolio companies. No single venture capital firm can have superior capabilities in all the areas of value-added when compared to a group of venture capital firms including the focal firm. As a result, syndication would be sought when the expected benefits from complementary value-adding resources and capabilities exceed the expected costs of splitting up the investment. Previous research has identified

certain empirical evidence suggesting that the value-added reasons dominate others as motives for syndication (Brander *et al*., 1999).

Syndication does not, however, ensure superior value added, because there is an incentive to free ride in the syndicate after the investment has been made. Venture capitalists spend a considerable amount of time with their portfolio companies (Sahlman, 1990). Thus, a venture capitalist may be tempted to let his/her syndicate partners be involved in the value-adding activities and concentrate his/her efforts on other ventures in his/her own portfolio. The problem of free riding is obviously smaller if the ownership share of the focal venture capitalist represents a considerable share of its portfolio, and if the syndicate partners have made an agreement that decreases incentives to free ride.

Sharing information on potential deals. Through their syndication relationships, venture capital firms exchange information with each other to find and evaluate investment opportunities, to obtain commitments and support, and to legitimate themselves as prestigious organisations (Bygrave, 1987). Information on potential deals, or deal flow, is essential to any venture capitalist to ensure that the investments can be selected from a wide set of alternatives. Venture capitalists select their investments in a screening process that consists of several stages of different levels of precision (Sahlman, 1990). As a result, only a small percentage of the initially observed potential deals end up in the portfolio as investments. To maximise the quality of the final portfolio, and to speed up the process of investing the fund commitments within the period agreed upon with the limited partners, venture capitalists aim at maximising their deal flow. Syndication relationships serve as a mechanism for spreading deal-related information to trusted partners, and as a mechanism to reciprocate prior invitations to syndicates and prior sharing of deal information (Bygrave, 1987; Lerner, 1994).

Spreading financial value at risk. A third potential motive for syndication is the sharing of financial risk. Rational investors diversify their portfolios to reduce idiosyncratic risk and to make their portfolios more efficient (Markowitz, 1952). However, venture capitalists find it more difficult to diversify their portfolio than public market investors because of the high informational asymmetries of the private investment market (Sahlman, 1990), and possibly also because of the smaller size of their funds and the difficulty of divesting underperforming investments. In order to achieve an optimal level of portfolio diversification, and to reduce their financial value at risk, venture capital firms may choose to syndicate large investments. Although financial risk sharing has been found to be a motive for syndication at least in the UK venture capital market (Lockett and Wright, 2001), empirical studies in general have not provided firm support on the motive of financial risk-sharing. Venture capitalists have been observed to syndicate frequently even if financial value at risk is low (Bygrave, 1987), and reasons related to value-adding capabilities have been found to dominate financial risk-sharing reasons (Brander *et al*., 1999).

Improved decision-making. Fourthly, syndication provides benefits from joint decision-making. Firms can share risk related to decision-making under uncertainty if they co-

operate (Wilson, 1968). Syndicating first-round venture capital investments in particular may lead to better decisions about whether or not to invest in the firms (Lerner, 1994). If several independent investors first check each other's willingness to invest in a potentially promising firm and then jointly invest in it, the selection they make may be superior to a decision based on only one decision-maker (Sah and Stiglitz, 1986). Such a hierarchical or at least partly hierarchical decision-making mechanism reduces the risk of selecting inferior companies in the portfolio. Furthermore, such mechanisms contribute to resolving the information asymmetry inherent in private investments. Empirical evidence suggests that venture capitalists indeed appear to syndicate when investment-related information is highly asymmetric (Bygrave, 1987). Thus, one potential motive for syndication is improved decision-making or reduced risk of adverse selection in the investment situations. Venture capitalists may also syndicate because existing investors in a venture have an incentive to overstate the value of the venture's shares when new investors are providing additional financing. The only way to avoid this opportunistic behaviour is for the existing lead investor to hold a constant share of equity (Admati and Pfleiderer, 1994), and therefore later-round investments must be syndicated.

Social reasons. The formation of syndication relationships may also reflect the venture capitalists' need to establish social status (Podolny, 2001). Firms with many relationships with other well-connected firms have high status and gain reputational benefits. As a result, venture capitalists may attempt to establish syndication relationships to generate and maintain status-enhancing organisational connections. Furthermore, reciprocity can be a particularly appropriate motive for repeat syndication with the same partners. Venture capitalists may invite others to join a deal in the hope of receiving reciprocal invitations to the future deals of the syndication partners (Lerner, 1994). Syndication can also act as a vehicle to expand the spatial radius of exchange of venture capital firms (Sorenson and Stuart, 2001). While venture capitalists generally prefer to invest in geographically close companies, syndication relationships appear to allow VCs to invest in more distant firms with trusted syndication partners.

Window dressing. Finally, 'window dressing' may motivate venture capital firms to syndicate with each other (Lerner, 1994). In order to be able to raise a new fund after closing the previous one, venture capitalists have to be able to demonstrate a good track record of past performance. Hence, venture capital firms may be tempted to enter deals that have proved to have a good chance of providing a successful exit in the future. As a result, venture capitalists may want to join investment syndicates in later-stage deals even at relatively high prices. Such investments allow the venture capital firms to associate themselves with the potential success stories of these investments. However, the window dressing hypothesis fails to explain syndication activities in the case of early-stage investments. This paper attempts to apply appropriate methods to control for window dressing in order to eliminate potential misinterpretations of the results.

2.2 Efficiency

Organisational 'efficiency' and 'effectiveness' are both related to the optimal functioning of organisations, but differ as theoretical concepts. Pfeffer and Salancick (1978) define efficiency as an organisation's internal evaluation of the number of resources consumed per a certain amount of output produced. Efficiency focuses on the process of achieving as many effective outputs as possible with a given number of inputs; or vice versa, achieving the given number of effective outputs with as few inputs as possible. Effectiveness, on the other hand, is the assessment of the organisation's output and activities performed by each of its external interest groups. Effectiveness can thus be defined only with respect to the assessment of a particular group. For example, the owners of a company might disagree with the employees on what is effective for the organisation. Owners might prefer the maximisation of their wealth, whereas employees might prefer the maximisation of their well-being. Effectiveness and efficiency are, thus, independent standards for evaluating organisations.

To understand the meaning of efficiency in the case of venture capital firms, a brief overview of the structure of the formal venture industry is necessary. Traditionally, venture capitalists raise money from their limited partners, invest the money in promising new ventures, harvest the investments by liquidating their holdings in an acquisition, a public offering, or some other type of an exit, and finally distribute the original funds and a majority of the returns back to the limited partners. The success of the initial fund or funds is critical to the venture capital firm's ability to raise further funds and continue operations. An additional important characteristic of venture capital investing is active involvement in the development of the portfolio companies during the period between investment and exit, the 'value added' of the investor (MacMillan *et al.*, 1988; Gorman and Sahlman, 1989; Rosenstein *et al.*, 1993; Sapienza, 1992; Sapienza *et al.*, 1996; Hellman and Puri, 2000; 2002).

The main interest groups of a typical venture capital firm tend to have a common perspective on the effectiveness of these firms. Firstly, from the limited partners' point of view, the objective of venture capital organisations is to maximise the value of the originally raised funds by selecting, managing, and developing the ventures in which these funds are invested. Thus, a venture capital firm is effective when it maximises the realised return on the limited partners' investment. Secondly, the main part of the general partners' compensation is generally a percentage of the return on the investments supplemented with a fixed percentage fee of capital under management. The management company, i.e. the general partners, is rewarded with a 20-25% stake of the returns to the limited partners in addition to a 1-2% annual managing fee on capital invested in the venture capital fund (Sahlman, 1990; Gompers and Lerner, 1999a). Thus, the venture capital firm is most effective from its general partners' point of view when the return on the invested funds is maximised. Thirdly, from a portfolio company's perspective, the venture capital firm is most effective when it helps the company to maximise the wealth of its shareholders. Finally,

from the macroeconomic perspective of society, venture capitalists are most effective when their actions create market value, foster entrepreneurship, and lead to the creation of new jobs and economic growth. This argumentation leads to a natural first definition of venture capitalist efficiency: venture capitalists are most efficient when they produce as high a return on their capital employed as possible by using a given number of other resources.

Measuring the efficiency of venture capital firms is difficult for an outside observer because of the lack of publicised information. The internal rate of return (IRR) of the firm's funds would be the most interesting operationalisation of efficiency, as the IRR illustrates the return on capital invested. However, these numbers are regarded as trade secrets, and reliable, industry-wide IRR figures on individual funds are not currently available. In spite of the lack of fund IRR data, comparing the frequency of successful exits across venture capital firms may provide a practically feasible proxy for efficiency. The track record of IPOs, for example, is a quantifiable and relevant performance measure for venture capitalists. Initial public offerings are often referred to as 'the golden exit' for VCs (Bygrave and Timmons, 1992). The largest valuations and returns to venture capitalists are most often realised in IPOs (Bygrave and Timmons, 1992). Although only a fraction of venture capital investments reach the IPO, most of the total value to the investors is created in these exits (Bygrave and Timmons, 1992; Gompers and Lerner, 1999b). Additionally, the valuations of the portfolio companies are ultimately formed in a competitive market in the IPO, and hence the IPO provides a reliable view of the market value of these companies. The frequency and value of portfolio company initial public offerings should thus be highly correlated to fund returns. As a result, a venture capital firm is efficient if it manages to create a large number of public companies from its portfolio companies. In this paper, we focus on examining the efficiency of venture capital firms in creating public companies.

2.3 Hypotheses

Instead of focusing on the reasons for syndication, this paper takes a macro-level approach to examine how syndication affects the efficiency of venture capital firms. To answer this question, we analyse two aspects of the potential impact of syndication on the efficiency of the firm. Firstly, we assess the effect of the frequency of syndication on firm efficiency. 'Frequency' refers to the regularity of engaging in a co-investment relationship when a prospective investment target is available to the venture capitalist. The frequency of syndication is high when the focal venture capital firm has syndicate partners in most of its deals, and low when the focal firm makes most of its deals alone. Secondly, we examine the impact of the diversity of the firm's syndication relationships. Diversity is high when the focal venture capital firm has a comparatively large number of different syndicate partners, and low when the firm has comparatively few syndicate partners relative to other venture capital firms.

Our first hypotheses consider the relationship between syndication and efficiency in creating public companies from portfolio companies. Creating public companies is

important for a venture capitalist for the various reasons discussed earlier, particularly the often very attractive exit valuations, and potential to build a reputation. The venture capital firm can affect its ability to make portfolio companies public in two ways. Firstly, it can attempt to select extremely promising and high-quality ventures in its portfolio. If the venture capital firm succeeds in picking the best companies, a high proportion of its portfolio is ultimately likely to go public. Secondly, and, many researchers argue, more importantly, the venture capital firm can engage itself in various value-adding activities (MacMillan *et al.*, 1988; Gorman and Sahlman, 1989; Rosenstein *et al.*, 1993; Sapienza, 1992; Sapienza *et al.*, 1996; Hellman and Puri, 2000; 2002) with an attempt to influence the development of the portfolio companies as positively as possible.

According to the theoretical motives for syndication, both the frequency of syndication and the diversity of syndication relationships affect these two potential mechanisms. Firstly, syndication relationships may lead to better investments decisions. Syndication relationships provide an enhanced flow of information on potential deals (deal flow). Venture capital firms that have a diverse set of syndication relationships may have a wide variety of ventures to choose from. If the venture capital firm's evaluation criteria are relative to the universe of ventures it observes, enhanced deal flow leads to the selection of inherently better companies because the venture capitalist chooses a certain ratio of the deal flow in its portfolio. If the evaluation criteria are absolute rather than relative, enhanced deal flow accelerates the venture capitalist's process of finding and selecting portfolio companies that fulfil the necessary criteria. Thus, venture capitalists with a rich deal flow may be able to create public companies more frequently than venture capitalists with a less extensive deal flow. Moreover, the higher the frequency of engaging in syndicated investments, the more the venture capitalist is able to benefit from the potential efficiency gains due to improved deal flow. In addition to deal flow issues, syndication typically leads to a hierarchical decision-making process in which the investment target must pass the evaluations of several independent investors (Wilson, 1968). As a result, syndication may lead to better decisions about whether or not to invest. Previous research on managerial decision-making (Amason, 1996) also suggests that employing a diverse team of decision-makers generally leads to better decisions.

Secondly, syndication relationships may provide the venture capitalist complementary value-adding capabilities. Instead of having to acquire their own specialised resources for the steering of all the portfolio companies, venture capitalists can utilise the expertise of their syndicate partners. Furthermore, the external relationships of the syndicate partners can be highly valuable to the focal venture capitalist. The partners may have, for example, good contacts with relevant investment banks, auditors, corporations, and potential portfolio company executives to be hired. Alone, the focal venture capitalist would have to establish relationships with all the external parties in order to add the same value as the syndicate partners can add together. By engaging in diverse syndication relationships, the focal firm can use its co-investors as sources of complementary value-adding resources and capabilities. Furthermore, the higher the frequency of engaging in syndicated investments,

the more the venture capitalist is able to benefit from the potential efficiency gains due to improved value-adding capabilities.

We formulate the following hypotheses:

> **Hypothesis 1:** *The diversity of syndication relationships is positively related to the venture capital organisation's efficiency in creating public companies.*

> **Hypothesis 2:** *The frequency of syndication is positively related to the venture capital organisation's efficiency in creating public companies.*

The research setting allows us additionally to test how efficiency gains deriving from the frequency and diversity of syndication depend on uncertainty. Firstly, the potential benefits related to decision-making are highest under high uncertainty. Individual decisions on highly uncertain investments involve high risk and often highly asymmetric information. Making justified investment decisions under high uncertainty is considerably more probable if the focal firm can supplement its own analyses with the evaluations of its syndicate partners. The typical hierarchical decision-making process of syndicates is likely to be most influential when the investment target is highly uncertain. As a result, syndicating first-round and most uncertain venture capital investments in particular may lead to better decisions about whether or not to invest (Lerner, 1994). Efficiency gains from improved decision-making through syndication may thus be most evident when uncertainty about the quality of the focal venture is high.

Secondly, the ability of venture capitalists to add value is particularly evident in the most uncertain (early-stage) ventures (Sapienza, 1992). Early-stage investments typically require significantly more involvement in the day-to-day operations of the business from the venture capitalists, whereas later-stage companies already have management structures in place and require less assistance in running the business. Syndication relationships can act as a vehicle to gather specialised value-adding resources to steer and monitor portfolio companies. Thus, the more uncertain (early-stage) the investments of the focal venture capital firm, the more syndication may provide efficiency gains in terms of access to value-adding resources and capabilities.

An additional possible implication from testing the moderating effect of uncertainty on the efficiency gains from syndication is the elimination of the potential role of window dressing as the dominant motive for syndication. In the case of window dressing, efficiency gains would be highest for firms with a high share of later-stage investments because window-dressing venture capitalists would aim at syndicating primarily later-stage deals to quickly associate themselves with initial public offerings. If the efficiency gains from syndication are higher for venture capitalists focusing on early-stage investments, window dressing is unlikely to explain the hypothesised relationship between syndication and firm efficiency. In contrast, such contingency on uncertainty would support arguments that syndication provides tangible benefits to the venture capital firm.

In sum, we expect uncertainty to moderate the relationship between syndication and the efficiency of venture capital firms in creating public companies:

> **Hypothesis 3**: *The more uncertain the venture capital organisation's portfolio, the more the diversity of syndication relationships affects the venture capital organisation's efficiency in creating public companies.*

> **Hypothesis 4**: *The more uncertain the venture capital organisation's portfolio, the more the frequency of syndication affects the venture capital organisation's efficiency in creating public companies.*

The efficiency in creating public companies from portfolio companies does not yet provide a comprehensive view of the efficiency of the venture capital firm. If the process of screening and completing deals is very slow, the final output of public companies per year will be low despite a high "hit rate" of producing IPOs. To address this issue, our final hypotheses consider investment completion efficiency. By this term, we mean the efficiency of identifying investment targets, evaluating them, and making the investment in those companies that fulfil the necessary criteria. This process is efficient when the venture capital firm can identify and process a large number of prospective deals in a given period. Venture capital firms that consume comparatively large quantities of time and general partner resources on screening, making the investment decision, and structuring the deal are comparatively inefficient in completing investments.

We argue that both the frequency and the diversity of syndication have an impact on the efficiency of venture capital firms in completing investments. Firstly, the frequency of syndication should have a positive effect on deal-making efficiency because syndication relationships allow venture capitalists to obtain more and richer information on potential deals. Syndication relationships provide investors with an efficient channel to exchange information with trusted partners (Bygrave, 1987). To reciprocate prior invitations to syndicated deals, venture capitalists also frequently invite their previous partners to deals that have passed their initial screening (Lerner, 1994). Because of the increase in the flow of potential deals, venture capitalists that syndicate may be able to alleviate part of the time-consuming information gathering and venture identification process. An improved access to the necessary information should also accelerate the decision-making process, ceteris paribus. In addition, the asymmetry of information between the venture and the focal venture capitalist decreases as richer information about the venture becomes available. As a result, venture capitalists that syndicate may be able to make investments consuming less time and internal effort than VCs who do not syndicate.

While the diversity of syndication relationships contributes to the richness of information available to the venture capital firm and may improve the ultimate decisions (Amason, 1996), the hierarchical decision-making process of investment syndicates (Wilson, 1968; Lerner, 1994) may also have a negative impact on the efficiency of completing investments. Syndicates involve several independent decision-makers, and the withdrawal of one or more

parties may result in others giving up the deal. As a result, the percentage of investments not passing the combined screen of the syndicate partners is high when the syndicate is large. Thus, the more syndicate partners there are on average participating the firm's prospective deals, the fewer investments the firm is likely to accept in a given period. On the other hand, research in managerial decision-making argues that strategic decision-makers may be able to take advantage of diversity without the adverse impacts of conflict (Amason, 1996). Venture capitalists with diverse syndication relationships might be able to benefit from the richness of information the relationships provide without suffering from a cumbersome decision-making process. As a result, diversity can be argued to have both negative and positive effects on the efficiency of the venture capital firm in completing investments.

We hypothesise:

> **Hypothesis 5:** *The frequency of syndication is positively related to the venture capital organisation's efficiency in completing investments.*
>
> **Hypothesis 6a:** *The diversity of syndication relationships is positively related to the venture capital organisation's efficiency in completing investments.*
>
> **Hypothesis 6b:** *The diversity of syndication relationships is negatively related to the venture capital organisation's efficiency in completing investments*

3 DATA AND METHODS

3.1 Data

While most of the previous research on venture capital syndication networks has focused on the creation of dyads between firms (Bygrave, 1987; Bygrave, 1988; Anand and Piskorski 2001), or the syndication of individual investments (Lerner, 1994; Brander *et al*., 1999), the focus of this paper is the venture capital firm. More precisely, we analyse a time series of yearly observations from each venture capital firm in our sample. The focus of the analysis is the interrelation between syndication and the efficiency of the venture capital firm.

Our sample consists of the 100 leading private U.S. venture capital organisations that we identified based on the number of portfolio companies the firms had invested in by the end of the year 2000. Sampling from the leading firms in the industry was necessary to ensure the availability and reliability of data. Previous studies on interorganisational networks and alliances have used a similar strategy (Gulati, 1995; Ahuja, 2000). In spite of the focus on the top 100 firms, our sample still provides considerable variation in terms of the variables examined in the analyses.

To construct the sample, we collected data on all venture capital investments made by the top 100 firms between 1986 and 2000 from Securities Data Corporation's Venture Economics and New Issues databases. Venture Economics has been used in previous

venture capital research (e.g. Bygrave, 1987; Lerner, 1994; Gompers, 1995; Gompers and Lerner, 1998). Venture Economics has gathered venture capital investment data since the 1970s using the annual reports of venture capital funds, personal contacts to funds' personnel, initial public offering prospectuses, and acquisitions announced in the media. The database contains information on over 150,000 private equity investments (one financing round consists of several single investments) and it is widely recognised as a leading source of U.S. venture capital investment data. The SDC New Issues database was used to gather the offer prices and shares outstanding after the offer for each initial public offering the portfolio companies of our sample VC firms made between 1986 and 2001.

Supplementary data were gathered from the back issues of the publications called *Pratt's Guide to Venture Capital Sources*. This publication lists the general partners, the key personnel, and a variety of other parameters for most of the U.S. venture capital firms each year. The most relevant records for our study are the lists of general partners. These data are reported consistently each year with names and positions. Using the Pratt's Guide data, we tracked the total number of partners and their names in each venture capital firm each year. We classified personnel as partners if their position title included one of the terms 'partner', 'vice president' or 'managing director'. To ensure further the validity of the Pratt's Guide general partner data, we collected the current résumés of 28% of the partners of our sample firms, and reviewed their career years in each venture partnership. We then compared Pratt's Guide listings of partners to the sub-sample of résumés without observing significant inconsistencies between these two sources.

The sample of investments was selected from the universe of all venture capital investments using multiple criteria. Firstly, we restricted the data set to contain only U.S. venture capitalists and investments. In addition, we restricted our sample to those U.S. venture capital partnerships that Venture Economics classifies as "independent private partnerships". Thus, we did not take into account investment bank affiliates, corporate investors, endowments, individuals, or other private equity investors. Secondly, we examined only investments into U.S. portfolio companies. Finally, we limited the sample to investments that are standard venture capital investments by removing records that Venture Economics classifies as "leveraged buyout", "secondary purchase", "open market purchase", "private investment in public company" or "turnaround". The data set includes 54,700 investments into 10,057 portfolio companies in the years 1986 – 2000.

As our analysis sample contains only the 100 U.S. largest venture capital partnerships, we cannot always observe all the syndication partners of a given firm because some of the partners may not figure among the 100 largest firms. This bias could lead to a situation in which the syndication partners of some firms were systematically left out. Therefore, we extended the original sample of 100 companies to include the 160 largest venture capital investors in order to check the robustness of our frequency and diversity measures. In fact, we can observe on average 44% of the firms that invested in each company, while the investments by the 160 largest firms capture over 90% of all the portfolio companies in the

Venture Economics database between 1986 and 2000. However, measuring the syndication variables for the 100 sample firms from the syndication network of the 100 largest venture capital firms produced qualitatively equal results to those we obtained by measuring the variables from the syndication network of the 160 largest firms. The results indicate that restricting the sample to the 100 largest firms only does not generate systematic errors in our syndication measures.

Previous research has examined smaller samples mainly because of the large amount of computing power required to handle the matrix of syndication relationships. For example, Bygrave (1987; 1988) used a sample of 1501 randomly chosen portfolio companies that had received the first round of funding, and were included in the Venture Economics database. Lerner (1994) studied the rationales for syndication using a sample of 651 investment rounds in 271 biotech companies. Brander *et al*. (1999) used Canadian data on 576 exists from 1991 to 1997. Hence, the sample in this paper represents so far the largest set of investments in venture capital syndication studies.

3.2 Variables

3.2.1 Venture capitalist efficiency

Because of the lack of public data on the internal rates of return of venture capital funds or their individual investments, our proxy for the efficiency of a venture capital firm is its ability to create highly valuable public companies from its portfolio companies. While this approach cannot fully address the financial impact of splitting up the investment and the potential future returns, it captures the impact of syndication on the rate of creating successful outcomes from the portfolio companies, and aims to serve as a solid starting point for further research and argumentation on the potential benefits and drawbacks of investment syndication. To test the hypotheses of this paper, we decompose the ability to create public companies into two parts: investment completion efficiency and efficiency in creating public companies from the companies chosen in the portfolio. The sooner a venture capital firm is able to identify prospective targets, make investments in them, and turn them into valuable public companies, the more efficient it is.

3.2.2 Efficiency in creating public companies

The return from a venture capital investment is realised when the venture capital firm makes an exit from a portfolio company. In the exit, the venture capital firm either sells its stake or distributes the shares to its limited partners. At this stage, the venture has typically reached a point in which venture capital financing no longer has a meaningful role. The exit thus serves as a clear ending point for venture capital financing. Although only a fraction of venture capital investments reach the IPO, most of the total value to the investors is created in IPO exits (Bygrave and Timmons, 1992; Gompers and Lerner, 1999b). As the

largest valuations and returns to venture capitalists are most often realised in IPOs, we choose to focus on measuring the venture capitalist's efficiency in creating public companies from portfolio companies. We conduct three analyses on the relative efficiency of the investors. Firstly, we calculate the ratio of companies that ultimately went public from the new companies selected in the portfolio in a given year. For example, we track the status of all new company investments made in 1986, and check how many of them ultimately went public. Secondly, we calculate the number of initial public offerings per firm general partner in a given year. Thirdly, we examine the market value the venture capital firm captured from these IPOs per general partner each year. The larger these ratios, the more efficient the venture capitalist.

3.2.3 Investment completion efficiency

If a venture capital firm is efficient in completing investments, it is able to identify, evaluate, and accept more investments in a given period with given quality criteria than an inefficient counterpart. Thus, efficiency in completing investments should lead to an increase in the number of completed investments relative to the quantity of resources available for the evaluation and selection activity. The investments venture capitalists make are either follow-up investments to existing portfolio companies, or investments to companies to which the focal venture capitalist has not invested before. In the first case, the investor is already familiar with the venture through the previous evaluations and potential board representation, whereas in the latter case the venture is to some extent unknown and thus requires extensive evaluation. Hence, it is of more interest to focus the analysis on investment completion efficiency only on investments in new companies rather than on re-investments in existing portfolio companies, as the evaluation and selection processes differ significantly.

To measure the efficiency of the venture capital firm in completing deals, we examine the number of new company investments made by the firm each year relative to the number of general partners in the firm. General partners usually participate in identifying promising investment targets, manage the investment process, and make the ultimate evaluation and selection decisions. We calculate the ratio of new company investments per general partner in a given year of the sample to measure the investment completion efficiency of the venture capital firm. The larger this ratio, the more efficient the investment completion process.

3.2.4 Diversity and frequency of syndication

In the strictest definition of syndication, two venture capitalist invest in the same venture in the same financing round. However, the Venture Economics data impose certain restrictions for measuring syndication according to the strictest definition. The records in the Venture Economics database occasionally overstate the number of financing rounds because of staged distributions of funds and variations in the reported dates of the source

data (Lerner, 1994; Gompers and Lerner, 1999b). However, towards the end of our sample period, Venture Economics argues that the data collection methods have been significantly improved, and that old records have partly been revised. To alleviate the problem of single venture rounds being recorded as several observations, we broaden the concept of syndication by defining it as two venture capital firms investing in the same venture within a year. This does not require the investments to occur in the same round, but rather within a relatively short period. We believe that this approach captures the syndication relationships between any two venture capitalists and alleviates the potential problems with the early records of our data. Because our unit of analysis is the firm-year observation, our definition of a syndication relationship should have no unexpected impacts on the final results.

We define the *diversity of syndication* in a given year as the average number of other venture capital firms that the focal firm co-invested with in each new company investment during that year. Further, we define the *frequency of syndication* as the number of the focal firm's syndicated investments divided by the total number of its investments in a given year.

3.2.5 Uncertainty

Uncertainty refers to the degree to which the future states of the world cannot be anticipated and accurately predicted. In venture capital investment situations, there is considerable uncertainty concerning the quality of the portfolio companies. A typical proxy for uncertainty in venture capital portfolio companies is the 'stage of development' of the company (e.g. Gompers and Lerner, 2000). Early-stage companies have short operating histories and have typically released a very limited amount of public data about themselves. Thus, uncertainty regarding the quality of potential deals is highest in the early stages of the venture's development. Later-stage companies are much less uncertain because of their longer operating histories and more deterministic paths of future development. Several empirical studies confirm these propositions (e.g., Ruhnka and Young, 1991).

We measure the uncertainty of the venture capitalist's investment portfolio by calculating the percentage of investments in early-stage, expansion stage and later-stage companies each year. Venture Economics classifies each investment into one of these categories according to the stage of development of the company at the time of the investment.[13] We assume that portfolios consisting mainly of early-stage companies are more uncertain than portfolios consisting mainly of later-stage investments.

[13] Venture Economics reports that the following definitions are used for the stages of development. Early stage: The company is developing its product and engages in initial marketing, manufacturing and sales activities. Expansion stage: The company needs working capital for the initial expansion in producing and shipping. It has growing accounts receivable and inventories. Although the company has clearly made progress, it may not yet be showing a profit. Later stage: The company needs financing for the major growth expansion. Its sales volume is increasing and it is breaking even or profitable. Funds are utilised for further expansion, marketing, and working capital or development of an improved product.

3.3 Control variables

Firm size and resources. The main resources of a venture capital firm are the capital to be invested, the human resources running the firm and its investments, and information on potential investment targets (Bygrave, 1987). Firm size and the scarcity or availability of resources are likely to have a significant effect on the efficiency of the firm, and thus need to be controlled for in the models.

To capture the overall size of the firm, we control for the market share of investments, calculated as the number of new companies in which the firm invested each year divided by the number of all new companies receiving venture capital financing in the sample that year.

We measure the firms' financial resources by tracking the amount of capital under management each year. When raising funds, venture capitalists negotiate capital commitments from limited partners and invest them gradually over a few years into promising target companies. The sum of these commitments in a firm is referred to as 'capital under management'. We calculate a control variable for financial resources as the sum of the non-expired venture capital funds, and exclude funds that are raised for investments in asset classes other than traditional venture capital, e.g. buyouts. More precisely, we include only funds that Venture Economics classifies as 'venture capital' in our sample. We further assume the expiration of a fund to take place within ten years of the vintage year, which Sahlman (1990) found to be the case in 72% of the funds in his sample. Thus, we calculate the total size of a fund as part of capital under management for the ten years after its raising was completed.

The number of general partners each year is taken from our combination of the records from Pratt's Guide to Venture Capital Sources and the résumés of the hand-collected general partner sub-sample. We recognise that the records from Pratt's Guide reflect the year up to the date of publication, and use each year's Pratt's Guide data for the previous year's entries. We further assume that the number of general partners during a single calendar year remains constant. In the rare cases whereby general partner data is unavailable from both sources for a certain year, we use the data of the previous year.

Unfortunately, it is not possible to observe directly the supply of investment targets ('deal flow') dealt with by the venture capital firms of the sample. The number and quality of business proposals are guarded trade secrets, and there are no records of the deal flow. However, as venture capital has been found to be highly local business (Sorenson and Stuart, 2001), firm location can be used as a proxy for the overall amount of potential deal flow available to the firm. Following the convention of earlier research (Gompers and Lerner, 2000), we supplement our size-related controls, such as the market share of investments, using dummy variables for location. In our sample, 48% of investments were in companies in California, 13.5% in Massachusetts, and 4.8% in Texas. VCs located in California made 40% of all investments, VCs in Massachusetts 21%, and those in New York 8%. Respectively, 53 VCs are located in California, 33 in Massachusetts and 15 in New

York. We use two dummy variables to indicate whether the VC firm is located in California, Massachusetts or another state.

Venture capital firm age. The age of venture capital firms has become a standard control variable in the analysis of venture capital firms (e.g., Gompers, 1996; Gompers and Lerner, 1999a). The older the firm, the more contacts, experience, and prominence it has. In addition, the younger the firm, the more it tries to establish a reputation by opportunistically striving towards successful exits. This is a phenomenon known as 'grandstanding' (Gompers, 1996). We thus control for age effects, and calculate the age of each firm in our sample based on the founding dates in the Venture Economics database. We cross-check the validity of these records using the back issues of Pratt's Guides. In some rare ambiguous cases, we found that Venture Economics had allocated venture capital investments to a firm before the reported founding date. In these cases, we set the company founding year as the year of its first investment recorded in the database.

Investment stage mix of investments. The stage of development of a venture affects both the risk and the expected time-to-exit of the venture capital investment in it. In addition, a firm investing exclusively in later-stage companies is likely to be involved in proportionally more IPOs than one investing in early-stage companies. We calculate the percentage of investments in early-stage, expansion stage, and later-stage companies for each firm each year according to Venture Economics classifications.

Industry mix of investments. We also control for potential industry effects. We use the classification that Venture Economics provides for each portfolio company to construct percentage-of-portfolio variables for each VC firm. The following industry sectors are covered in the data: communications, computer hardware, computer software, semiconductors/electronics, Internet communications, Internet/computer related, and non-high-technology ventures.

Time-dependency. As our sample is a time series of cross-sections, it is necessary to control for differences between sample years. In all regressions, we include dummy variables for the sample years.

3.4 Statistical methods

To adequately test the hypotheses of this paper, we attempt to construct a set of robust statistical models. Because our analysis needs to tackle an unbalanced time series – cross-sectional panel data set of firm-year observations, straightforward statistical methods that assume there to be no heteroskedasticity, unobserved heterogeneity, or first-order autocorrelation, are inapplicable. While we run also conventional OLS regressions for comparison, we present only the results of the theoretically more robust time-series cross-sectional generalised least squares (GLS) regressions with fixed-effects specifications. This approach simultaneously controls for potential first-order autocorrelation across the subsequent observations of the same firm and heteroskedasticity across the observations of

the different firms, and utilises robust maximum-likelihood estimates for the model coefficients.

To control for unobserved heterogeneity in our sample, we choose to utilise the fixed firm effects approach. A fixed-effects model is appropriate when inferences are made conditional to the sample, whereas a random-effects model should be chosen when inferences are made for the entire population (Hsiao, 1986). Since our syndication measures are conditional to the sample, the first approach was selected as more appropriate. However, we found the differences in the results to be marginal if random-effects models are used. While pooled ordinary least squares models provide qualitatively similar results, the statistical approach adopted in this study gives a more realistic view of the magnitude, standard errors, and significance of the individual regression coefficients.

4 RESULTS

4.1 Descriptive statistics

Table 1 reports the descriptive statistics and correlations for the sample of 1333 yearly observations on the 100 venture capital firms in the sample. The average age of the firms is 17.7 years. On average, the firms have 5.8 general partners. The industry mix of investments is relatively even, and most of the industry share averages are approximately 8%-14% of the total portfolio. Exceptions are the Internet sectors, which represent the most recently established and thus the smallest industries of our longitudinal sample. The average portfolio includes 33% early-stage firms, 39% expansion-stage firms, and 24% late-stage firms.

Over two thirds of all venture capital investments in the sample are syndicated. The average frequency of syndication is 68%, suggesting that venture capitalists frequently engage in syndication relationships. On average, venture capitalists have 1.25 syndicate partners per portfolio company, and invest in 8.4 new companies in a year, amounting to 1.46 new companies per general partner per year. The IPO ratio across all investments is 0.26, which is roughly comparable to the old venture capital rule of thumb of one breakthrough per five investments (Bygrave and Timmons, 1992). This corresponds to 2.2 IPOs per year per venture capital partnership, or 0.39 IPOs per year per general partner.

Table 1 Descriptive statistics and correlation matrix of the firm-year observations

	Min	Max	Mean	Std. dev.
Investments in new companies / partner / year	0	8.5	1.46	1.20
Ratio of ultimate initial public offerings out of new investments in a given year	0	1.0	0.26	0.25
Number of IPOs / partner / year	0	5.0	0.39	0.45
Value of IPOs / partner / year (BUSD)	0	1.0	0.04	0.13
Frequency of syndication (% of portfolio companies)	0	1.0	0.68	0.24
Diversity of syndication (Avg. no. of syndication partners / company)	0	8.0	1.49	0.98
Venture capital firm age (years)	0.5	65	17.7	10.5
Market share of investments (%)	0.0	8.3	1.0	0.8
Number of general partners	1	22	5.8	3.0
Capital under management (BUSD)	0.1	4.0	0.25	0.36
Share of investments to medical (%)	0	100	13	16
Share of investments to biotech (%)	0	100	8	13
Share of investments to software (%)	0	100	20	18
Share of investments to hardware (%)	0	100	9	12
Share of investments to Internet, computer-related (%)	0	100	6	12
Share of investments to semiconductors (%)	0	100	8	12
Share of investments to communications (%)	0	100	15	16
Share of investments to Internet communications (%)	0	56	3	6
Share of investments to non-high-technology (%)	0	100	14	17
Share of investments to early stage ventures (%)	0	100	33	21
Share of investments to expansion stage ventures (%)	0	100	39	21
Share of investments to later-stage ventures (%)	0	100	24	19

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Investments / partner / year	1.00													
2	Ratio of IPOs / investments	-0.05	1.00												
3	No. of IPOs / partner / year	0.50	0.61	1.00											
4	Value of IPOs / partner / yr	0.37	0.22	0.54	1.00										
5	Frequency of syndication	0.13	0.19	0.24	0.12	1.00									
6	Diversity of syndication	-0.07	0.31	0.24	0.01	0.57	1.00								
7	Uncertainty * diversity	0.11	0.26	0.32	0.09	0.47	0.64	1.00							
8	Uncertainty * frequency	0.22	0.15	0.29	0.16	0.59	0.31	0.79	1.00						
9	Market share of deals	0.36	0.06	0.25	0.30	0.14	-0.05	0.03	0.13	1.00					
10	Capital under mgmt	0.27	-0.16	-0.08	0.11	-0.05	-0.21	-0.17	-0.07	0.38	1.00				
11	No. of general partners	-0.13	-0.04	-0.18	0.08	-0.07	-0.16	-0.13	-0.09	0.45	0.55	1.00			
12	Firm age	-0.09	-0.11	-0.23	-0.03	-0.02	-0.10	-0.12	-0.07	0.09	0.23	0.32	1.00		
13	California	0.20	0.07	0.20	0.18	0.31	0.22	0.30	0.31	0.14	0.09	-0.03	-0.11	1.00	
14	Massachusetts	-0.06	0.01	-0.05	-0.05	0.00	-0.01	-0.04	-0.05	-0.05	0.01	0.11	0.06	-0.39	1.00
15	Medical %	-0.05	0.03	0.00	-0.04	0.03	0.01	0.06	0.06	0.02	-0.06	-0.01	-0.04	0.00	-0.08
16	Biotech %	-0.07	0.17	0.08	-0.02	0.10	0.07	0.13	0.14	0.03	-0.09	-0.05	0.06	-0.05	0.02
17	Software %	0.04	-0.02	0.01	0.06	0.06	0.02	-0.02	0.04	0.03	0.02	-0.01	-0.09	0.13	0.07
18	Hardware %	-0.04	0.18	0.18	-0.03	0.19	0.39	0.29	0.15	-0.01	-0.17	-0.11	-0.15	0.14	0.02
19	Internet/computer %	0.32	-0.25	-0.12	0.09	-0.09	-0.26	-0.22	-0.13	0.03	0.45	0.20	0.18	0.11	-0.02
20	Semiconductors %	-0.08	0.12	0.05	-0.01	0.13	0.25	0.19	0.08	0.04	-0.04	0.02	0.00	0.06	0.05
21	Communications %	0.00	-0.01	0.00	0.05	0.12	0.06	-0.03	0.00	0.02	-0.01	-0.05	-0.01	-0.04	0.05
22	Internet/communic. %	0.29	-0.23	-0.12	0.10	-0.10	-0.22	-0.17	-0.08	0.06	0.39	0.22	0.18	0.09	-0.04
23	Early stage %	0.21	0.07	0.21	0.12	0.16	0.06	0.66	0.81	0.10	-0.08	-0.08	-0.06	0.19	-0.05
24	Later stage %	-0.18	-0.05	-0.11	-0.02	-0.02	0.06	-0.31	-0.38	-0.02	-0.03	-0.02	0.10	-0.09	0.05

		15	16	17	18	19	20	21	22	23	24
15	Medical %	1.00									
16	Biotech %	0.12	1.00								
17	Software %	-0.30	-0.24	1.00							
18	Hardware %	-0.16	-0.13	-0.06	1.00						
19	Internet/computer %	-0.15	-0.19	0.01	-0.25	1.00					
20	Semiconductors %	-0.17	-0.06	-0.16	0.15	-0.16	1.00				
21	Communications %	-0.24	-0.18	-0.14	-0.11	-0.10	-0.07	1.00			
22	Internet/communic. %	-0.15	-0.18	0.03	-0.22	0.47	-0.14	0.02	1.00		
23	Early stage %	0.04	0.12	0.02	0.08	-0.09	0.02	-0.06	-0.03	1.00	
24	Later stage %	0.03	0.03	0.00	-0.01	-0.08	0.06	0.03	-0.06	-0.48	1.00

The pairwise correlations listed in Table 1 indicate that the hypothesised relationships exist. The correlations between the syndication variables and the dependent variables are positive except that the impact of the diversity of syndication relationships on deal-making efficiency is negative. Furthermore, all cross-correlations among the independent variables are below 0.8, the usual threshold for a multicollinearity problem. Standard tests for multicollinearity did neither suggest problems with the specifications of the models.

4.2 Efficiency in creating public companies

To test whether the propensity and strategy to syndicate investments affect the efficiency of venture capital firms to create public companies from their portfolio companies, we attempt to construct a set of robust and relevant statistical models. Table 2 presents the results of a fixed-effects GLS analysis of the efficiency of venture capital firms in creating public companies from portfolio companies. We test the impact of the frequency of syndication and the diversity of syndication relationships using the yearly share of ultimate portfolio company initial public offerings from investments in new companies as the dependent variable. The regression coefficients are presented with the corresponding *z*-statistics. Additionally, the analyses include year dummies that are not presented in the table.

The basis model in Table 2 shows that firms focusing on certain industries and firms that have many general partners produce a significantly higher ratio of portfolio company IPOs than other firms. The remaining models focus on testing the hypotheses. Firstly, Hypotheses 1 and 2 proposed that the diversity of syndication relationships and the frequency of syndication are positively related to the venture capital organisation's efficiency in creating public companies, respectively. Although the second model in Table 2 indicates that the frequency of syndication is positively related to the IPO efficiency of the sample firms, the third model with the diversity variable included shows that the diversity of syndication has a positive and much more significant effect on the ability to create initial public offerings from portfolio companies. Venture capitalists that have a diverse set of syndication relationships seem to be more efficient in generating IPOs from their portfolio companies than competitors with a more restricted set of syndication partners.

Hypotheses 3 and 4 proposed that the more uncertainty there is, the more the diversity of syndication relationships, and the frequency of syndication affect the venture capital organisation's efficiency in creating public companies, respectively. In the fourth model of Table 2, we add an interaction variable of the diversity of syndication relationships and the percentage of early stage investments. The coefficient appears positive and significant, as expected. The fifth model repeats the test using an interaction between syndication frequency and the percentage of early-stage investments. However, the interaction variable does not appear significant. Uncertainty in the venture capitalist's portfolio seems, thus, to intensify the efficiency gains from the diversity of syndication relationships, but does not interact with the frequency of syndication.

We argue that there are at least two reasons why the diversity of syndication relationships outweighs the frequency of syndication in the efficiency of creating public companies from portfolio companies. Firstly, diversity defines the scope of the resource-capability base available for value-adding activities. If the venture capitalist has a diverse set of syndication partners, it is comparatively more likely that the partners can provide complementary resources and capabilities that can add value to the portfolio company. Secondly, diversity enhances the focal venture capital firm's ability to include the most promising ventures in the portfolio. A diverse set of relationships ensures a rich flow of deals from multiple sources. To get deal flow, it is potentially not necessary to engage frequently in syndication relationships. Rather, the number of active relationships counts. While the frequent utilisation of syndication relationships seems to have a positive effect on efficiency when diversity is not taken into account, these two reasons support the result that the diversity of the relationships is the dominant factor in efficiency gains from syndication in creating public companies.

Table 2 includes an alternative column of coefficients for the full regression model. Both of the full models use the same methodology but different time spans of data. The model in the fifth column of the table use the entire sample data from 1986 to 2000, whereas the model in the sixth column uses data ranging only from 1986 to 1991. The results discussed above are confirmed by the right-hand side regression on the restricted data set. The inclusion of the restricted time span is necessary to demonstrate the robustness of the results, and to eliminate the potential impact of different investment stage strategies of the venture firms. While the number of observed portfolio company IPOs may be sensitive to the time the investments have been in the portfolio, running the analyses on the latter time span of data should alleviate the problem. For example, the probability of year 2000 investments reaching an IPO by the end of our observation period in 2001 is relatively low, whereas the probability of year 1990 investments of reaching an IPO by the same time is much higher. In contrast, practically all potential IPOs should have been realised by 2001 for the historical period of 1986-1991, irrespective of the focal firm's choice of investment stage focus. We further check the robustness of the results using different time spans, and find that the regressions provide qualitatively equivalent results to the ones reported in the table.

Table 2 Efficiency in creating public companies from portfolio companies: the ratio of ultimate IPOs out of new investments

The dependent variable is the ratio of companies that ultimately reached the initial public offering of investments in new companies each year. Cross-sectional time-series GLS regression with fixed firm effects is applied. Regression coefficients and *z*-statistics are presented; year dummies are included but not shown.

	Ratio of ultimate IPOs out of new investments / year, 1986 – 2000										1986 – 1991	
Frequency of syndication		.064	**	.010		.011		.040			.015	
		(2.64)		(.36)		(.38)		(.82)			(.18)	
Diversity of syndication				.057		.043		.038			.074	
				(5.82)	***	(3.06)	***	(2.42)	**		(3.13)	***
(Diversity) x (early stage %)						.059		.060			.050	
						(1.79)	*	(1.80)	*		(1.49)	+
(Frequency) x (early stage %)								-.084			-.052	
								(.73)			(.25)	
Market share of investments	.654	.416		1.052		1.075		1.036			.816	
	(1.12)	(.71)		(1.75)	+	(1.79)	+	(1.72)	+		(.71)	
Capital under management (log)	.000	.000		.000		.000		.000			.000	
	(.48)	(.50)		(.21)		(.19)		(.18)			(1.68)	+
Number of general partners	.007	.007		.006		.005		.005			.000	
	(3.40)	*** (3.22)	***	(2.69)	**	(2.64)	**	(2.64)	**		(.01)	
Firm age (log)	-.010	-.004		-.006		-.006		-.006			-.015	
	(1.16)	(.46)		(.69)		(.63)		(.63)			(1.06)	
Firm located in California?	.018	.015		.009		.008		.007			.045	
	(1.52)	(1.25)		(.76)		(.65)		(.61)			(2.05)	*
Firm located in Massachusetts?	.008	.009		.011		.011		.011			.061	
	(.57)	(.67)		(.76)		(.77)		(.75)			(2.53)	*
Medical %	.145	.122		.016		.013		.014			-.105	
	(3.40)	*** (2.73)	**	(.33)		(.26)		(.28)			(1.46)	
Biotech %	.494	.502		.342		.349		.347			.388	
	(9.53)	*** (9.17)	***	(5.97)	***	(6.06)	***	(6.05)	***		(3.47)	***
Software %	.196	.166		.054		.057		.058			.052	
	(5.24)	*** (4.19)	***	(1.24)		(1.29)		(1.31)			(.74)	
Hardware %	.252	.294		.142		.147		.148			.114	
	(4.55)	*** (4.90)	***	(2.22)	*	(2.31)	*	(2.32)	*		(1.29)	
Internet, computer-related %	.336	.356		.277		.280		.277			.480	
	(4.93)	*** (5.13)	***	(3.85)	***	(3.88)	***	(3.84)	***		(1.72)	+
Semiconductors %	.345	.216		.090		.091		.090			.114	
	(6.31)	*** (3.60)	***	(1.42)		(1.43)		(1.41)			(1.21)	
Communications %	.147	.121		.013		.017		.017			-.075	
	(3.72)	*** (2.86)	**	(.27)		(.37)		(.37)			(1.08)	
Internet, communications %	.293	.331		.262		.266		.265			.096	
	(2.55)	* (2.91)	**	(2.28)	*	(2.31)	*	(2.31)	*		(.17)	
Early stage %	-.021	-.040		-.051		-.101		-.064			.011	
	(.64)	(1.19)		(1.51)		(1.96)	*	(.89)			(.09)	
Later stage %	-.006	-.018		-.066		-.061		-.060			-.153	
	(.17)	(.48)		(1.71)	+	(1.58)		(1.56)			(2.55)	*
Constant	-.274	-.310		-.211		-.200		-.213			.249	
	(5.99)	*** (6.42)	***	(3.98)	***	(3.71)	***	(3.76)	***		(4.09)	***
Wald χ^2-statistic	695.1	713.9		755.2		756.8		756.9			201.4	
p-value	0.000	0.000		0.000		0.000		0.000			0.000	
N	1333	1333		1333		1333		1333			477	

*** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level; 1-tailed tests for hypothesised relationships, 2-tailed tests for controls

4.3 Investment completion efficiency

The second type of analysis considers the impact of syndication on the efficiency of venture capital firms in completing new investments. Table 3 presents five GLS models that regress the independent variables on the number of completed investments relative to the number

of firm general partners each year. The regression coefficients are presented with the corresponding *z*-statistics. Although not presented in the table, all regression analyses include year dummies to control for potential differences between years.

The first model tests the effects of all control variables. As expected, controls related to size and firm resources – market share of investments and capital under management – are highly significant. The coefficient of firm age is negative, which indicates that younger firms tend to make more investments per general partner than more established firms. Location in California or Massachusetts is positively related to the dependent variable, presumably because of the higher supply of potential investment targets in those regions (Gompers and Lerner, 2000). Firms that are active in early-stage investments appear to make more investments per general partner than firms focusing on later-stage ventures.

In Hypothesis 5 we suggested that the frequency of syndication is positively related to the venture capital organisation's investment completion efficiency, whereas Hypothesis 6b predicted that the diversity of syndication relationships is negatively related to investment completion efficiency. Models 2 and 3 include the frequency of syndication and the diversity of syndication relationships as independent variables. The coefficient for syndication frequency turns out to be highly significant and positive, whereas the diversity of syndication relationships seems to be an insignificant explanatory variable. However, when both variables are added at the same time, and the cross-correlation between frequency and diversity is taken into account, frequency appears positive and significant, and diversity negative but still insignificant. The final model thus provides results in line with the negative pairwise but insigificant correlation between diversity and investment completion efficiency (Table 1). The results suggest that the frequency of syndication increases the deal-making efficiency of venture capital firms by increasing the manageable number of new company investments per general partner, whereas high diversity of syndication relationships has no clear impact on the efficiency in completing investments.

The results are in line with our predictions. As outlined in the hypotheses, venture capitalists that syndicate frequently benefit from their syndicate partners. Syndication accelerates the process of finding investment targets and completing investments. Similarly, frequent engagement in syndicated investments may enhance the evaluation of the investment targets by allowing the general partners of the focal firm to concentrate better on their core competence areas of the evaluation process.

However, although the frequency of syndication is a significant factor contributing to the efficiency of completing investments, the diversity of syndication relationships tends to have both negative and positive effects. While frequent syndication with a limited number of syndication partners may allow venture capitalists to institutionalise and rationalise the investment evaluation process, collaboration with a diverse group of syndication partners is more time-consuming. It takes more time to make decisions, set up meetings, and manage the relationships, if syndication partners are numerous. Hierarchical or at least partly hierarchical decision-making in the syndicate also decreases investment acceptance rates.

On the other hand, diversity also brings access to richer information, and makes decision-making easier. The results suggest that neither of these mechanisms significantly dominates the other one.

Table 3 Investment completion efficiency: the number of new investments per general partner and year

The dependent variable is the number of the firm's investments in new companies each year divided by the number of the firm's general partners that year. Cross-sectional time-series GLS regression with fixed firm effects is applied. Regression coefficients and *z*-statistics are presented; year dummies are included.

	Investments into new portfolio companies / partner / year							
Frequency of syndication			.191				.358	
			(2.56)	**			(4.06)	***
Diversity of syndication					.031		-.029	
					(1.24)		(1.00)	
Market share of investments	75.3		72.5		75.4		71.6	
	(26.52)	***	(25.70)	***	(26.61)	***	(25.11)	***
Capital under management (log)	.000		.000		.000		.000	
	(6.27)	***	(6.56)	***	(6.76)	***	(6.88)	***
Number of general partners	-.165		-.165		-.177		-.174	
	(21.56)	***	(21.39)	***	(23.06)	***	(22.52)	***
Firm age (log)	-.082		-.146		-.096		-.132	
	(2.77)	**	(4.56)	***	(3.14)	**	(4.11)	***
Firm located in California?	.131		.107		.171		.123	
	(3.13)	**	(2.45)	*	(3.96)	***	(2.80)	**
Firm located in Massachusetts?	.121		.107		.162		.134	
	(2.86)	**	(2.47)	*	(3.68)	***	(3.03)	**
Medical %	.253		.060		-.215		-.258	
	(2.02)	*	(.45)		(1.54)		(1.80)	+
Biotech %	.014		-.157		-.484		-.496	
	(.10)		(.98)		(2.91)	**	(2.86)	**
Software %	.360		.133		-.130		-.187	
	(3.30)	***	(1.11)		(1.03)		(1.42)	
Hardware %	.338		.245		-.101		.003	
	(2.02)	*	(1.36)		(.54)		(.02)	
Internet, computer-related %	1.453		1.137		.704		.687	
	(6.70)	***	(5.08)	***	(3.09)	**	(2.96)	**
Semiconductors %	-.090		-.321		-.552		-.631	
	(.57)		(1.87)	+	(3.27)	***	(3.51)	***
Communications %	.397		.155		-.098		-.193	
	(3.34)	***	(1.23)		(.72)		(1.40)	
Internet, communications %	1.837		1.357		1.140		1.063	
	(4.71)	***	(3.49)	***	(2.96)	**	(2.76)	**
Early stage %	.931		1.002		.714		.778	
	(9.35)	***	(9.48)	***	(6.79)	***	(7.11)	***
Later stage %	-.136		-.178		-.410		-.374	
	(1.30)		(1.64)		(3.67)	***	(3.29)	***
Constant	1.692		2.065		2.443		2.452	
	(11.14)	***	(12.62)	***	(14.14)	***	(13.90)	***
Wald χ^2-statistic	2306.8		2210.6		2165.6		2178.1	
p-value	0.000		0.000		0.000		0.000	
N	1333		1333		1333		1333	

*** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level; 1-tailed tests for hypothesised relationships, 2-tailed tests for controls

4.4 Overall efficiency of the venture capital firm

As a concluding analysis, we demonstrate how syndication affects the overall efficiency of the venture capital firm by combining the efficiency in creating public companies from

portfolio companies and the efficiency in completing investments in two overall efficiency measures. Firstly, we calculate the product of the ratio of initial public offerings out of investments made and the ratio of investments made per general partner in a given period, and arrive at an overall measure of the efficiency of the venture capital firm: Initial public offerings per general partner each year. Secondly, we calculate the market value generated in these initial public offerings per firm general partner each year. These aspects of efficiency are important especially for the general partners since the compensation of the general partners is mostly dependent on the magnitude of returns generated per partner (Gompers and Lerner, 1999a).

The analysis in Table 4 considers the overall efficiency of the venture capital firm. In models 1–3, we regress the number of initial public offerings per year per general partner on the same independent and control variables as in Table 2. As model 2 indicates, the diversity of syndication has a positive effect on the number of IPOs relative to the number of general partners. Venture capitalists who have a diverse set of syndication partners seem to be able to participate in significantly more IPOs relative to their general partner resources than other venture capitalists. The regression coefficient of the syndication frequency variable indicates that the frequency of syndication is positively but not significantly related to firm efficiency.

Model 3 supplements the regression model with interaction terms between the share of early-stage investments of the firm's investments, and the syndication variables. The share of early-stage investments reflects the uncertainty of the venture capitalist's portfolio. The coefficient of the interaction between the frequency of syndication and portfolio uncertainty is positive, as expected. Even though model 2 shows that the positive contribution of frequency on firm efficiency is not significant for all the VC firms of the sample, venture capitalists focusing on early-stage investments gain benefits from frequent syndication relationships. Similarly, the interaction variable between uncertainty and the diversity of syndication relationships is positive and significant. Portfolio uncertainty thus moderates the relationship between the diversity of syndication and firm efficiency.

Models 4 and 5 repeat the same tests using the market value generated in the initial public offerings per general partner each year as the dependent variable. Model 4 shows that both the frequency and the diversity of syndication have a positive impact on the efficiency of the VC firm, but that only diversity is significant. Furthermore, model 5 indicates that the interactions between portfolio uncertainty and the syndication are positive but not significant. The moderating effect of portfolio uncertainty is much less significant than in the case of the number of IPOs per general partner possibly because early-stage portfolios potentially generate, on average, smaller portfolio company IPOs than later-stage portfolios.

To demonstrate the robustness of the results, we run the same regressions on a restricted data set with observations from 1986-1991 only. All models show qualitatively similar results to the ones obtained from the full data set. As an example of the robustness tests, model 6 reports the results of a regression similar to model 3 but utilises the restricted data set.

Table 4 *Efficiency of venture capital firms: the number and value of initial public offerings per general partner and year*

The dependent variable is the number of portfolio company initial public offerings produced per general partner each year in models 1,2,3, and 6, and the value of portfolio company IPOs produced per general partner each year in models 4 and 5. Cross-sectional time-series GLS regression with fixed firm effects is applied. Regression coefficients and *z*-statistics are presented; year dummies are included but not shown.

	Number of IPOs / general partner / year , 1986 – 2000			Value of IPOs / gen. part. / year , 1986 – 2000		Model 3, 1986 – 1991
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Frequency of syndication		.033	-.040	.065	.001	-.022
		(.84)	(.67)	(1.27)	(.01)	(.22)
Diversity of syndication		.052	-.004	.047	.028	-.003
		(3.72) ***	(.21)	(2.74) **	(1.19)	(.12)
(Diversity) x (early stage %)			.196		.072	.123
			(4.33) ***		(1.15)	(1.83) *
(Frequency) x (early stage %)			.187		.187	.285
			(1.41) +		(.97)	(1.08)
Market share of investments	18.7	18.4	18.8	21.0	21.2	18.9
	(15.21) ***	(14.48) ***	(15.13) ***	(8.70) ***	(8.75) ***	(8.28) ***
Capital under management (log)	.000	.000	.000	.000	.000	.000
	(.38)	(.74)	(.85)	(1.39)	(1.35)	(3.23) ***
Number of general partners	-.026	-.028	-.030	-.005	-.006	-.062
	(8.07) ***	(8.25) ***	(8.86) ***	(1.10)	(1.28)	(9.86) ***
Firm age (log)	-.025	-.051	-.050	-.039	-.036	-.064
	(2.03) *	(3.40) ***	(3.31) ***	(2.15) *	(1.91) +	(2.92) **
Firm located in California?	.100	.085	.071	.104	.096	.197
	(5.35) ***	(4.08) ***	(3.40) ***	(3.01) **	(2.73) **	(5.91) ***
Firm located in Massachusetts?	.024	.026	.022	.027	.027	.118
	(1.31)	(1.22)	(1.04)	(1.08)	(1.05)	(3.39) ***
Medical %	.109	-.034	-.027	-.163	-.166	-.310
	(2.06) *	(.51)	(.42)	(2.16) *	(2.17) *	(3.12) **
Biotech %	.288	.218	.223	.035	.028	.273
	(4.88) ***	(2.53) *	(2.64) **	(.36)	(.29)	(1.77) +
Software %	.205	.035	.056	-.004	.002	-.144
	(4.37) ***	(.56)	(.91)	(.06)	(.03)	(1.76) +
Hardware %	.248	.132	.122	-.172	-.161	.022
	(3.40) ***	(1.38)	(1.32)	(1.63)	(1.47)	(.17)
Internet, computer-related %	.400	.336	.352	.301	.302	.853
	(4.62) ***	(3.32) ***	(3.64) ***	(2.03) *	(2.03) *	(2.26) *
Semiconductors %	.104	-.087	-.081	-.098	-.100	-.186
	(1.62)	(1.06)	(1.02)	(.91)	(.93)	(1.92) +
Communications %	.110	-.041	-.015	.020	.034	-.094
	(2.35) *	(.69)	(.26)	(.30)	(.48)	(1.01)
Internet, communications %	.317	.311	.319	.602	.591	3.001
	(1.88) +	(1.75) +	(1.87) +	(2.45) *	(2.39) *	(1.48)
Early stage %	.099	.054	-.269	.102	-.085	-.335
	(2.52) *	(1.09)	(3.06) **	(1.62)	(.73)	(2.16) *
Later stage %	-.072	-.146	-.102	-.051	-.029	-.128
	(1.64)	(2.77) **	(1.97) *	(.86)	(.46)	(1.63)
Constant	-.112	.037	.127	-.281	-.227	.622
	(1.76) +	(.46)	(1.57)	(2.74) **	(2.12) *	(7.07) ***
Wald χ^2-statistic	823.1	733.8	818.7	283.1	281.0	418.4
p-value	0.000	0.000	0.000	0.000	0.000	0.000
N	1333	1333	1333	1330	1330	477

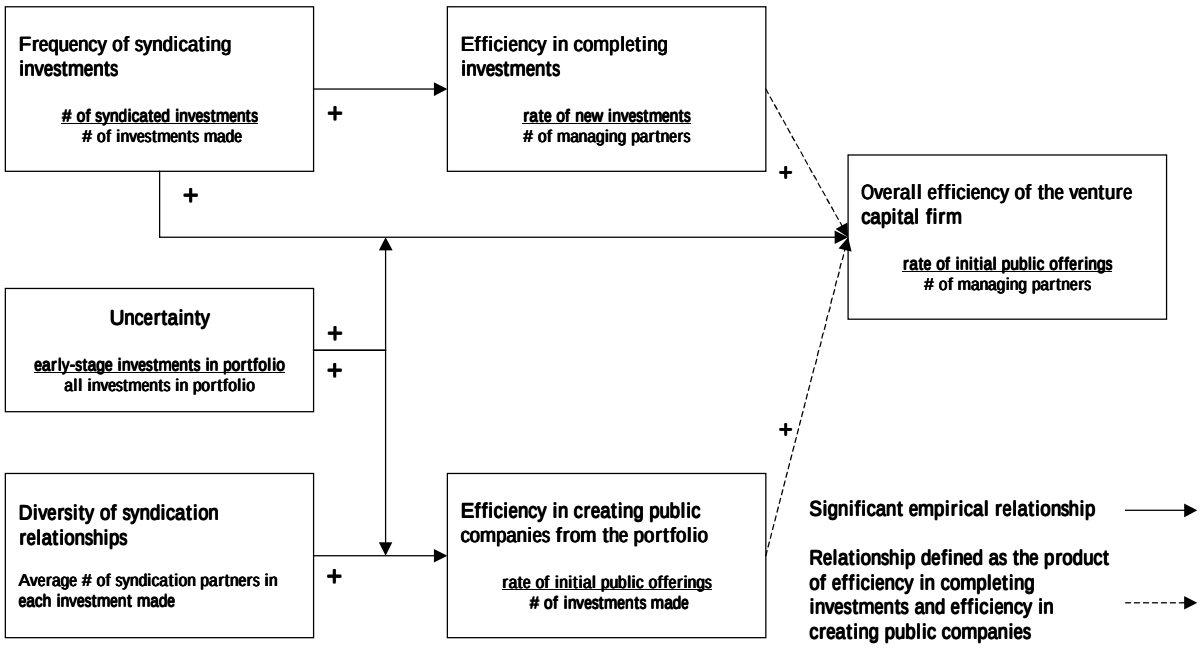
*** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level; 1-tailed tests for hypothesised relationships, 2-tailed tests for controls

The results provide additional support for our hypotheses. The diversity of syndication has a positive effect on venture capital organisations' overall efficiency, and the impact is greater the more uncertainty there is in the portfolio of the focal venture capital firm. The

frequency of syndication, on the other hand, is consistently insignificant in the regressions. In contrast, frequency has a significant positive impact on the number of portfolio company IPOs when portfolio uncertainty is high. Overall, the results indicate that it is beneficial for the general partners of venture capital firms to engage in diverse syndication relationships especially when typical investment situations are uncertain. Furthermore, a diverse network of syndication partners contributes especially to the venture capital firm's ability to create public companies from an uncertain portfolio of investments, and improves value generation from portfolio company IPOs in both uncertain and less uncertain portfolios.

The final results are summarised in Figure 1, which presents the relationships found significant in the regressions and the connection between investment completion efficiency, efficiency in creating public companies from portfolio companies, and the overall efficiency of the venture capital firm. The results clearly demonstrate the positive impact of diversity on the ability to generate public companies, the positive impact of frequency and the insignificant impact of diversity on the efficiency in completing deals, and the moderating effects of uncertainty. Similarly, Figure 1 demonstrates the observed positive impact of frequency on overall firm efficiency. On the other hand, the diversity of syndication relationships appears to improve the "hit rate", but not have an effect on the "throughput" of the venture capital firm.

Figure 1 Impact of syndication on the efficiency of venture capital firms



4.5 Robustness of the results

To ensure the robustness of the above results, we conduct several confirmatory analyses. Firstly, we attempt to eliminate *window dressing* as a potential explanation for the results by testing whether the impact of syndication is contingent on the stage distribution of the portfolio of the focal venture capital firm. If window dressing explained the relationship between syndication and the ability to create public companies from portfolio companies, the impact of syndication would seem to be highest for firms with a high proportion of later-stage investments because venture capitalists engaging in window-dressing would aim at syndicating primarily later-stage deals to associate themselves quickly with upcoming initial public offerings. However, our results in Tables 2 and 4 show that efficiency gains from syndication are consistently higher for venture capitalists focusing on early-stage investments. The higher the share of early-stage investments in the venture capital firm's portfolio, the more the diversity and frequency of syndication affect the ability to create public companies from the portfolio. Thus, window dressing is unlikely to explain the observed relationships between syndication and firm efficiency.

Secondly, our methodology also significantly reduces the probability that *reverse causality* were a problem in our analyses. Reverse causality would imply that investments that are syndicated were more likely to go public along some unobservable dimensions, which would "hard wire" the results. We take this potential problem into account in two ways. Firstly, we utilise a large number of control variables that might affect the propensity of firms to syndicate and generate initial public offerings. Secondly, we argue that the positive contingency on uncertainty indicates that investment syndication provides tangible benefits to venture capital firms. If reverse causality explained our results, especially later-stage investments that are highly probable IPO candidates should attract syndication partners, but uncertain early-stage investments should not be nearly as attractive targets for syndication. However, our results consistently show that the impact of syndication is highest for venture capital firms that have a large share of *early-stage* investments. Thus, reverse causality is not likely to explain the results.

Thirdly, we recognise that the ratio of IPOs out of new company investments may be biased downwards from the actual value towards the end of the time range of our sample. This results from the fact that new company investments require a certain amount of time before the exit can be realised. The median time between the first investment by the focal venture capitalist into a company and the IPO of the company is 2.9 years[14] in the sample, which indicates that a significant share of the investments

[14] The figure may seem small taking into account the traditional venture capital holding period of about five years from first investment to exit (Bygrave and Timmons 1992). However, this figure is the median of the investment holding periods for venture capital firms *including* firms that invested for the first time in the venture only in the very late financing rounds. These short holding periods make the median equal-weighted time-to-IPO seem relatively short.

made in 1998 had not reached the potential IPO by 2001, our last point of observation for initial public offerings. Thus, we observe too few IPOs in the last years of our sample for all venture capitalists, and especially for firms concentrating on early-stage investments. As the bias favours firms focusing on later-stage investments, we expected that the analysis would tend to reject the key hypotheses, making the results more significant if the IPO data could be made complete. In spite of that, we test the robustness of our results by restricting the sample to several different periods, and compare the results to ones obtained from the entire sample. The restricted models reported in Tables 2 and 4 that use IPO variables as dependent variables demonstrate that the choice of time range should not pose problems in the analysis.

As mentioned in the section describing the method, we also test the impact of the choice of the sample of firms on the syndication measures. While the approach shown in the analyses utilises syndication measures derived from the syndication network of the 100 largest U.S. VC firms, we also run the regressions on syndication measures derived from an extended database of the 160 largest U.S. venture capital firms. This approach captures more syndication relationships for almost all of the firms, but does not alter the results of the regressions. Measuring the syndication variables for the 100 sample firms from the syndication network of the 100 largest venture capital firms produced qualitatively equal results to those we obtained by measuring the variables from the syndication network of the 160 largest firms. Table 5 summarises the key results using the alternative syndication measures in the regression equations.

Table 5 Robustness of key results to alternative syndication measures

The syndication measures are calculated from an extended sample of the 160 largest U.S. venture capital organisations. Cross-sectional time-series GLS regression with fixed firm effects is applied. Regression coefficients and *z*-statistics are presented; control variables are included but not shown.

	Ratio of IPOs / new investments		Investments / partner / year	Number of IPOs / partner / year		IPO value / partner / year
Frequency of syndication	.012	.039	.390	.030	-.035	.070
	(.40)	(.80)	(4.29) ***	(.76)	(.63)	(1.30)
Diversity of syndication	.050	.039	-.028	.058	-.003	.048
	(4.58) ***	(2.51) **	(0.98)	(3.99) ***	(.15)	(2.78) **
(Diversity) x (early stage %)		.059	.358		.193	
		(1.79) *			(4.21) ***	
(Frequency) x (early stage %)		-.082			.188	
		(.69)			(1.40) +	
Control variables	The same control variables are included in all models as in Tables 2 – 4					
Wald χ^2-statistic	732.9	737.1	2125.2	780.2	828.2	279.1
p-value	0.000	0.000	0.000	0.000	0.000	0.000
N	1333	1333	1333	1333	1333	1330

*** Significant on the 0.001 level, ** Significant on the 0.01 level, * Significant on the 0.05 level, + Significant on the 0.1 level; 1-tailed tests for hypothesised relationships, 2-tailed tests for controls

5 DISCUSSION AND CONCLUSIONS

This paper set out to examine the relationship between syndication and the efficiency of venture capital firms. In spite of the stream of previous theoretical and empirical research on the reasons to syndicate venture capital investments, knowledge of the benefits and drawbacks of syndication for the venture capital firm is still thin. In this paper, we took a macro-level approach to examine how syndication affects the efficiency of venture capital firms, and presented and elaborated the key benefits and disadvantages that arise from the syndication of investments with other venture capitalists. Furthermore, we formulated six hypotheses on the impact of the frequency of syndication and the diversity of syndication relationships on the efficiency of venture capital firms. The hypotheses were tested using a comprehensive data set consisting of the investments of the 100 largest U.S. venture capital organisations between 1986 and 2000.

The results provide support for the hypotheses regarding the impact of syndication on the efficiency of venture capital firms. The key lever of enhancing the 'hit rate', or the efficiency in creating public companies from portfolio companies, appears to be the diversity of the syndication relationships. The broader a set of syndication relationships a venture capital firm has, the better is its ability to make its portfolio companies public. Furthermore, our results demonstrate that uncertainty moderates the relationship between the diversity of syndication and the efficiency in creating public companies. The more uncertain the venture capital firm's investment portfolio, the more efficiency gains the diversity of syndication relationships provides. The positive contingency on portfolio uncertainty also allows us to reject the window dressing hypothesis and reverse causality as potential alternative sources of our findings. Finally, we found that investors who frequently engage in syndication relationships can leverage their syndication partners to increase their overall efficiency and, in particular, efficiency in completing deals. The gains from the frequency of syndication were also found to be positively contingent on portfolio uncertainty.

Our paper has several important implications. Firstly, it provides understanding of appropriate syndication strategies for venture capitalists. Both the diversity and frequency of syndication relationships appear important in terms of efficiency especially when uncertainty is high. Diversity, however, seems to be more powerful in explaining efficiency in the creation of public companies from portfolio companies. Diversity improves the "hit rate" of venture capitalists. Diversity also improves the market value that the venture capital firm can capture from its portfolio company IPOs. Thus, having a diverse set of syndication partners is a potential success factor in venture capital investing especially in the case of early-stage investments.

Secondly, venture capitalists can use syndication as a vehicle to adjust their deal completion efficiency. The frequency of syndication improves the overall efficiency of venture capital firms especially by improving the efficiency in completing investments.

Frequent syndication with a limited number of syndication partners results in a larger number of deals being completed within a given period. The "throughput" of the firm thus increases with the frequency of syndication. However, as the diversity of syndication relationships increases, deal completion rates and the "throughput" may start to decrease, although our results suggest that the impact is not significant. Nevertheless, venture capitalists should attempt to balance their frequency of engaging in investment syndicates and the diversity of their syndication relationships to find an optimal combination of impact on the "hit rate" and the "throughput" of their firm.

Finally, researchers can benefit from this paper in terms of a better understanding of how investment syndication affects the venture capital firm and its portfolio of investments. This paper has attempted to start a structured academic discussion on the benefits and drawbacks of investment syndication for venture capital firms.

There are naturally limitations in this paper. Firstly, measuring the frequency of portfolio company initial public offerings does not quite correctly reward venture capitalists that are specialised in acquisition exits or generate large returns on their investments through exit vehicles other than the IPO. Although IPOs probably provide by far the highest average returns and yield several other benefits to the venture capital firm, acquisitions can also be successful and significantly contribute to the efficiency of a venture capital firm. The lack of comprehensive data on acquisitions and company valuations in these exits effectively hinders rigorous empirical investigations of the impact of syndication on the success of acquisition exits. An analysis of the internal rates of return of the funds of the venture capital firm instead of only the success of portfolio company IPOs could also supplement the results obtained in this paper. However, the lack of publicised IRR figures for a large enough set of venture capital funds prevented us from conducting this analysis.

Secondly, we have not been able to fully analyse the price of syndication. While it seems clear that venture capitalists can enhance their efficiency through syndication, it is not clear how much they must pay for splitting up the investment. It is possible that firm prominence is a significant factor in determining how the investment and the benefits from syndication are split up. An analysis of this question would require more detailed information on how the financing round is apportioned among the venture capital firms participating in the syndicate than is currently available, but would also be a significant supplement to our empirical understanding of venture capital syndication.

A third limitation arises from the fact that our data set is geographically limited to the United States. Expanding the analysis to European countries and other parts of the world would reveal potential country-specific effects of syndication. Despite the limitations, we believe that our approach provides a valid and valuable starting point for more detailed analyses on syndication, the efficiency, and the performance of venture capital firms.

This paper has left also other interesting questions open. Syndication clearly provides benefits in terms of efficiency, but this paper has not analysed the determinants of the existence of the syndication relationships. Why do certain syndication relationships exist? The past performance and the prominence of the focal investor are likely to be potential explanatory factors of the exchange partners' willingness to syndicate. On the other hand, a preferred position in the co-investment network should presumably be related to better performance and prominence. Further research could examine how the relative position of venture capitalists in the syndication network affects their prominence and relative performance. Network theory provides appropriate measures, such as power and centrality, to assess whether certain venture capitalists act as key nodes of the network in addition to their potentially frequent relationships with a selected set of other firms.

REFERENCES

Admati AR, Pfleider P. 1994. Robust financial contracting and the role of venture capitalists. *Journal of Finance* 49(2): 371 – 402.

Ahuja G. 2000. The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal* 21: 317 – 343.

Amason AC. 1996. Distinguishing the Effects of Functional and Dysfunctional Conflict on Strategic Decision Making: Resolving a Paradox for Top Management Teams. *Academy of Management Journal* 39(1): 123 – 148.

Anand B, Piskorski MJ. 2001. *Money can't buy my love: Financial resources and network positions in the formation of venture capitalist syndicates*. Working paper, Harvard Business School.

Brander J, Amit R, Antweiler W. 1999. *Venture Capital Syndication: Improved Venture Selection versus the Value-Added Hypothesis.* Working paper, University of British Columbia.

Bygrave WD. 1987. Syndicated Investments by Venture Capital Firms: A Networking Perspective. *Journal of Business Venturing* 2(2): 139 – 154.

Bygrave WD. 1988. The Structure of the Investment Networks of Venture Capital Firms. *Journal of Business Venturing* 3: 137 – 158.

Bygrave WD, Timmons JA. 1992. *Venture Capital at the Crossroads*. Harvard Business School Press: Boston, MA.

Gompers PA. 1995. Optimal Investment, Monitoring, and the Staging of Venture Capital. *Journal of Finance* 50(5): 1461 – 1489.

Gompers PA. 1996. Grandstanding in the Venture Capital Industry. *Journal of Financial Economics* 42(1): 133 – 156.

Gompers PA, Lerner J. 1998. *The Determinants of Corporate Venture Capital Successes: Organizational Structure, Incentives, and Complementarities*. NBER Working Paper No. W6725.

Gompers PA, Lerner J. 1999a. An analysis of compensation in the U.S. venture capital partnership. *Journal of Financial Economics* 51(January): 3 – 44.

Gompers PA, Lerner J. 1999b. *The Venture Capital Cycle.* The MIT Press: Cambridge, MA.

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

Gorman M, Sahlman WA. 1989. What Do Venture Capitalists Do? *Journal of Business Venturing* 4(4): 231 – 248.

Gulati R. 1995. Social structure and alliance formation patterns: A longitudinal analysis. *Administrative Science Quarterly* 40(4): 619 – 652.

Hellmann T, Puri M. 2000. The Interaction between Product Market and Financing Strategy: The Role of Venture Capital. *Review of Financial Studies* 13(4): 959 – 984.

Hellmann T, Puri M. 2002. Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence. *Journal of Finance* 57(1): 169 – 197.

Hsiao C. 1986. *Analysis of panel data*. Cambridge University Press: Cambridge.

Lerner J. 1994. The Syndication of Venture Capital Investments. *Financial Management* 23(3): 16 – 27.

Lockett A, Wright M. 2001. The syndication of venture capital investments. *Omega* 29: 375 – 390.

MacMillan IC, Kulow DM, Khoylian R. 1988. Venture Capitalists' Involvement in Their Investments: Extent and Performance. *Journal of Business Venturing* 4(1): 27 – 47.

Markowitz H. 1952. Portfolio Selection. *Journal of Finance* 7(1): 77 – 91.

Pfeffer J, Salancick GR. 1978. *The External Control of Organizations: A Resource Dependence Perspective.* Harper & Row: New York, NY.

Podolny JM. 2001. Networks as Pipes and Prisms of the Market. *American Journal of Sociology* 107(1): 33 – 60.

Rosenstein JA, Bruno V, Bygrave WD, Taylor NT. 1993. The CEO, Venture Capitalists, and the Board. *Journal of Business Venturing* 8(2): 99 – 113.

Ruhnka JC, Young JE. 1991. Some Hypotheses about Risk in Venture Capital Investing. *Journal of Business Venturing* 6(2): 115 – 133.

Sah RK, Stiglitz JE. 1986. The Architecture of Economic Systems: Hierarchies and Polyarchies. *The American Economic Review* 76(4): 716 – 727.

Sahlman WA. 1990. The Structure and Governance of Venture-Capital Organizations. *Journal of Financial Economics* 27: 473 – 521.

Sapienza HJ. 1992. When Do Venture Capitalists Add Value? *Journal of Business Venturing* 7(1): 9 – 27.

Sapienza HJ, Manigart S, Vermeir W. 1996. Venture Capitalist Governance and Value-added in Four Countries. *Journal of Business Venturing* 11(6): 439 – 469.

Sorenson O, Stuart T. 2001. Syndication Networks and the Spatial Distribution of Venture Capital Investments. *American Journal of Sociology* 106(6): 1546 – 1588.

Wilson R. 1968. The theory of syndicates. *Econometrica* 36(1): 119 – 132.

ESSAY 4:

HOW THE RICH BECOME RICHER IN VENTURE CAPITAL: FIRM PERFORMANCE AND POSITION IN SYNDICATION NETWORKS

Abstract. This paper compares resource-based and social structural explanations for the network positions and performance of organisations. Our distributed lag analysis of an extensive data set of U.S. venture capital investments and their syndicate structures between 1986 and 2000 suggests that venture capital firms in central network positions increase their market share of portfolio company initial public offerings in subsequent years. Consistent with the social structural argument, our results further demonstrate that prior network position tends to determine future position. Analyses of causality show that past network position tends to dominate the observable quality of firm resources as a determinant of the subsequent performance and position of the firm. Our results further imply that the structure of venture capital syndication networks is rigid and involves high barriers to entry, and that the acquisition of general partners contributes to changes in existing network positions.

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1 INTRODUCTION

Over the last decade, research on strategic alliances and related collaborative relationships has identified that up to a limit, connectedness to other firms in collaborative interorganisational networks improves firm performance. Interorganisational relationships have been found to improve innovation output (Ahuja, 2000b; Baum *et al.*, 2000), revenue growth (Eisenhardt and Schoonhoven, 1990; Baum *et al.*, 2000), growth of research and development (Baum *et al.*, 2000), profit rates (Hagedoorn and Schakenraad, 1994), organisational survival rates (Mitchell and Singh, 1996; Baum and Oliver, 1991), and market valuations in initial public offerings (Stuart *et al.*, 1999).

Two main theory streams have provided complementary explanations for why interorganisational relationships are beneficial, and why firms establish linkages. Firstly, arguments based on the resource-based view of the firm posit that firms obtain access to needed assets or complementary resources through the linkages. While resources are typically firm-specific, not available for purchase in factor markets, and need to accumulate and develop in the firm over a long period in order to provide competitive advantage (Dierickx and Cool, 1989), interorganisational relationships provide a vehicle through which firms can obtain much quicker access to resources that create competitive advantage (Ahuja, 2000a). Thus, the resource-based view of inter-organisational network formation argues, firms establish linkages to gain access to complementary and attractive resources possessed by others.

Secondly, collaborative relationships provide organisations with social benefits. Well-connected firms gain informational and reputation benefits from their linkages to other firms (Gulati, 1995; 1999). Prior exchange relationships serve as indicators of the reliability of potential partners, and the exchange network spreads information efficiently between connected firms (Gulati 1995; 1999). Furthermore, economic sociology argues that an economic actor's rewards are largely a function of position in the actor's social structure (White, 1981; Baker, 1984; Podolny, 1993). Actors with central positions tend to gain higher rewards than peripheral actors. A key argument for why central actors tend to outperform others is that network positions are reflections of the status of the firm (Podolny, 1993; 1994). Status acts as a signal of the quality of the firm's products and reduces the costs actors would need to incur in order to gain confidence that the products are of acceptable quality. Because of these position-based benefits, the social structural view of network formation argues that a firm's ability to form new relationships is determined by the set of opportunities provided by its network position. Central and high-status actors or firms attract more and higher-status exchange partners than peripheral actors. Thus, the social structural view argues that network formation is endogenous, and prior position tends to determine future position.

While previous research on interorganisational exchanges has made significant contributions, especially to the formation of exchange relationships both from the resource-based perspective and the social structural perspective, the connection between firm performance and its position in collaborative networks has not received as much attention. In particular, the current body of knowledge lacks explicit analyses of causality in the relationship between firm performance and position in collaborative networks. It is unclear whether past performance or past positions lead to central positions in collaborative networks, and whether central positions lead to improved performance. Assuming that other actors evaluate firms' resources on the basis of the observable quality of the firms' outputs, examining this causal relationship is equivalent to examining whether the resource-based reasons or the social structural reasons are the dominant determinants of interorganisational exchange.

This paper sets out to examine the relationship between firm performance and position in the syndication network of the U.S. venture capital industry. We propose that venture capitalists that have gained a central position in the syndication network will consequently outperform their peers as a result of resource-based and social structural benefits. To understand causality in the hypothesised relationship between firm performance and network position, we formulate two additional competing hypotheses. On one hand, the social structural hypothesis implies that past position is the major determinant of subsequent position. According to this view, the willingness of other firms to co-operate with the focal firm depends on the number and position of its existing partners. On the other hand, resource-based reasoning suggests that the observable quality of the firm's resources attracts exchange partners and improves the network position of the focal firm.

Our empirical analysis is based on a longitudinal set of firm-year observations constructed from an extensive database of over 50,000 U.S. venture capital investments in the period 1986 – 2000. The venture capital industry provides a good environment for testing our hypotheses for various reasons. Firstly, the formation of interorganisational linkages is significantly more frequent in venture capital syndication than in the case of alliances that typically have been used as the empirical data for studies on interorganisational exchanges. Frequent observations on linkage formation should reduce unobserved heterogeneity that can be caused by changes in the characteristics of the exchange partners over time. Secondly, syndication is clearly defined, and syndication events are easily observable, whereas the proper identification of alliances typically requires rigorous judgement by the researchers. Thirdly, examining venture capital syndications also allows us to treat network position as a dynamic variable rather than a static, cross-sectional variable. This enables rigorous empirical testing of causality in the hypothesised relationships.

The paper is organised as follows. Section 2 discusses the theoretical setting, and builds the testable hypotheses. Section 3 presents the data and the methods used. Section 4

presents the empirical results. Finally, conclusions and implications are discussed in section 5.

2 THEORY AND HYPOTHESES

2.1 Resource-based view of interorganisational relationships

The resource-based view of the firm (Penrose, 1959) suggests that firms seek competitive advantage by obtaining control over those factors that increase their competitiveness above that of their closest rivals (Wernerfelt, 1984). 'Resources' are factors that can provide competitive advantage and have four distinctive characteristics (Barney, 1991). Firstly, resources must be valuable to the firm, either in terms of lower input costs or higher prices of outputs. Secondly, resources must be rare or firm-specific. If resources were commonly held, they would not differentiate firms from one another, and thus would not provide competitive advantage. Thirdly, resources must be imperfectly imitable to sustain the competitive advantage in the long term. Finally, resources must not be substitutable. If resources could be replaced using strategically equivalent substitutes, they would not provide competitive advantage. These factors imply that resources cannot be instantaneously developed. Rather, they require time to accumulate. Thus, resources are typically asset stocks that have less value when separated from the creating organisation (Dierickx and Cool, 1989).

Interorganisational exchange relationships provide firms with an opportunity to resolve the problem of having to accumulate resources for a long time before gaining any competitive advantage (Ahuja, 2000a). Through interorganisational relationships, firms can obtain access to assets that fulfil the four conditions for resources that create competitive advantage. In addition to the accumulation problem, collaboration resolves the problem of tradability in the case of non-tradable resources. Thus, organisations can benefit from exchange relationships because they can access attractive resources that can complement their existing resource pool. Firms form linkages to obtain access to needed assets (Hagedoorn and Schakenraad, 1994; Nohria and Garcia-Pont, 1991), or to learn new skills (Kogut, 1988). Additionally, the resource dependence theory (Pfeffer and Salancick, 1978) suggests that organisations engage in exchange relationships because their resources are interdependent. Actors attempt to reduce uncertainty and acquire resources that are not easily available on the market. Thus, linkage formation reflects firms' incentives to collaborate (Ahuja, 2000a). The greater the firm's competitive resource deficiency and the need to obtain the relevant resources, the more willing the firm is to form linkages.

According to the resource-based view of network formation, firms select their exchange partners on the basis of the observable quality of their resources, and organisations with a complementary or superior resource base are the most attractive partners. Organisations

can identify the quality of the potential partners' resources by acquiring information on their current observable resource endowments, or by examining the past performance of the partner's actions (Baum *et al.*, 2000). The resource-based view assumes that the availability of exchange opportunities is not a constraint, and that the supply of linkage partners is infinitely elastic (Hagedoorn and Schakenraad, 1994). Initial position in the network is not relevant; the attractiveness of the partner's resources determines whether a dyad is formed or not. This assumption is naturally debatable.

Inter-firm linkages provide the focal organisation with several benefits (Ahuja, 2000a). Network connections help it to improve financial performance and survival prospects (Baum and Oliver, 1991; Baum *et al.*, 2000; Hagedoorn and Schakenraad, 1994; Mitchell and Singh, 1996), develop and absorb technology (Powell *et al.*, 1996), and withstand economic shocks (Miner *et al.*, 1990). Additionally, interorganisational relationships have been found to improve innovation output (Ahuja, 2000b; Baum *et al.*, 2000) and market valuations in initial public offerings (Stuart *et al.*, 1999). However, to be able to form the linkages that may yield these benefits, the firm should be attractive to collaboration partners. The resource-based argument is that the focal firm should have an attractive stock of resources that it can exchange with the partners.

2.2 Social structural view of interorganisational relationships

An alternative view of the formation of exchange relationships stems from social structural theory and theories of social networks. According to this view, prior exchanges are major determinants of the emergence of future exchanges (Granovetter, 1985; Gulati, 1995). Exogenous factors such as the resources of the network actors may be important for initiating co-operative exchanges but are insufficient in determining with whom the organisation decides to exchange. Because organisations face substantial uncertainty in obtaining reliable information on the attributes, quality, and trustworthiness of potential new exchange partners, they tend to prefer their existing partners in future exchanges (Gulati, 1995). Extended experience with linkages reduces the focal firm's uncertainty about partners because prior relationships provide information on the partners' capabilities and likely behaviour of the partners. Prior relationships also enable the institutionalisation of the collaboration relationships and the creation of organisational routines around them (Ahuja, 2000a). Thus, network dyads are most likely formed between actors that have previously co-operated with each other.

Status effects are another important social factor in the formation of exchange relationships. In his classic article on the reward systems of science, Merton (1968) recognised the self-reinforcing positive effects of status. Eminent scientists tend to receive a disproportionate amount of credit for their contributions, and collaborative papers tend to earn a disproportionate amount of credit for the author with the highest prior reputation. People remember primarily the author they are already familiar with from the past – the author with the higher status. This phenomenon, the 'Matthew Effect'

(Merton, 1968), has been later documented in several contexts (e.g., Podolny, 1993). In addition to actors in science, economic actors with high status should be able to achieve above-average returns. The status of an economic actor refers to the perceived quality of the economic actor's offering relative to the perceived quality of those of the actor's competitors (Podolny, 1993). Status serves as a signal of the quality of the actor and the actor's offerings (Podolny, 1993; 1994). Thus, it is easier for a high-status actor to attract the exchange partners it desires than it is for a low-status actor.

A common argument among sociologists is that status is reflected as position in a social network (Bonacich, 1987; Podolny, 1993). High-status actors can be seen as central nodes in the network of firms and their resources. Central position makes economic actors desirable exchange partners, and allows them to gather resources from a large set of relationships. Associations with a large number of high-status partners increases the attractiveness of the central actors as partners, which leads to the formation of new exchange relationships and even higher centrality and status.

In conclusion, central positions in collaborative networks will positively impact a firm's performance and opportunities to form further linkages because of at least three mechanisms (Gulati, 1995; 1999; Ahuja, 2000a). Firstly, central firms can obtain information about linkage formation opportunities from their partners and their partners' partners. Because of an enhanced flow of information, central actors have more opportunities to form linkages, and they possess more accurate information on the quality of the potential exchange partners. Secondly, a central position is in itself a signal of the status and reliability of the focal firm. An extensive number of existing partnerships with other high-status actors create trust among potential new partners through accumulated reputation and references from the existing partners. It is thus less risky for other firms to collaborate with highly central firms than with firms whose collaborative behaviour is unknown. Similarly, product market participants reward high-status firms because status reduces the costs the market participants would need to incur to gain confidence that the products of the firm are of acceptable quality. Thirdly, centrality in the network acts as a signal that the focal firm has access to other highly central actors. Potential exchange partners thus have the opportunity to connect to other high-status actors in addition to the focal firm. As a result, central firms attract proportionally more exchange partners than peripheral firms.

2.3 Exchange theories in the venture capital context

Venture capital firms frequently engage in collaborative relationships with other venture investors because investment syndication is common in the industry. Just as commercial banks syndicate loans, venture capitalists often share their risk capital investments. Syndicates are typically formed by a lead investor who contacts other potential investors and records their commitments to invest. Several motives encourage venture capitalists to co-operate and establish syndicates. Firstly, syndication partners can improve the lead

investor's capabilities to add value to the portfolio company (Brander *et al.*, 1999). Venture capitalists have heterogeneous skills and information and can contribute to the success of portfolio companies through several mechanisms (MacMillan *et al.*, 1988; Sapienza, 1992; Hellman and Puri, 2002). Secondly, syndication relationships allow venture capitalists to share information on future deals (Bygrave, 1987; Sorenson and Stuart, 2001). Thirdly, syndication allows the spread of financial risk, although empirical evidence has provided contradictory results on the sharing of financial resources as a motive for syndication (Bygrave, 1987; Lockett and Wright, 2001). Fourthly, syndicates allow making better investment decisions because several investors can evaluate the venture largely independently (Wilson, 1968; Lerner, 1994). Fifthly, venture capitalists may syndicate to enhance their social status (Podolny, 2001). Sixthly, the 'window dressing' phenomenon of venture capital funds has been argued to be one possible explanation for syndication (Lerner, 1994).

Previous research on the exchange relationships of venture capital firms has examined both the resource-based and social structural explanations for tie formation in investment syndication, although most studies of syndication have adopted a relatively informal approach.

The resource-based stream of arguments has argued that venture capitalists need, in principle, at least three kinds of resources (Bygrave, 1987). Firstly, VCs need the capital to be invested in the portfolio companies. The second necessary set of resources is the supply of potential investment targets, i.e. promising new ventures that are short of capital. Finally, the VC firm must find competent human resources to make investment decisions and steer the portfolio companies. In principle, syndication could serve as a resource exchange vehicle in these three areas. Firstly, syndicate partners can provide additional capital, and can thus decrease the financial commitment needed from the lead investor. This shares risk inherent in large or speculative investments, and enables investments that are out of the lead investor's operating scope in terms of monetary size. Secondly, syndication provides venture capitalists with a flow of information on prospective investment targets (Bygrave, 1987; Sorenson and Stuart, 2001). Thirdly and finally, VCs share their decision-making resources in the syndication network by utilising the evaluation capabilities of their syndicate partners when screening and selecting investment targets. Syndication also allows VCs to use their syndicate partners' expertise and relationships with outside parties, such as corporations, investment banks and law firms, to add value to their investments. Thus, the resources of the potential exchange partners may represent the primary determinant for the formation of syndication relationships.

Previous research also includes theoretically less formal empirical investigations on the formation of venture capitalist networks. Bygrave (1988) examined the structure of venture capital syndication networks in the U.S., and found that venture capital firms tend to form tightly coupled cliques that exchange information swiftly. For example,

firms focusing on highly innovative ventures formed a tightly coupled group, and concentrated on maintaining the existing exchange relationships instead of actively creating new ones. However, these tightly coupled groups sometimes establish contacts with weakly tied firms that are potential sources of information fresh to the tightly coupled network. Nevertheless, Bygrave's (1988) empirical results indicate that the structure of the syndication network is among the key determinants of tie formation. Bygrave (1988), however, attributes exchanges to resource needs instead of a social structural argument.

The social structural view on venture capital has started to emerge as an alternative approach to venture capital syndication. Adopting a status-based perspective, Podolny (2001) examined how the position of venture capital firms in the network or syndication relationships affects their choice of market segments. Whereas high status tends to drive venture capitalists towards less risky market segments, structural holes in the network imply a shift from low-risk to high-risk segments. Strategy choice and market behaviour are, thus, embedded in the network of syndication relationships. Further supporting the social structural view, Anand and Piskorski (2001) found that venture capital firms that have central positions in the syndication network can establish co-operation relationships with other firms regardless of their financial resources, whereas peripheral firms can establish ties only if they have substantial financial resources. As a result, central venture capitalists tend to sustain their positions.

2.4 Hypotheses

The resource-based and social structural views on interorganisational collaboration allow us to test and elaborate the relationship between firms' economic performance and position in a collaboration network. Several arguments derive from these theories for formulating appropriate hypotheses on the effect of network position on firm performance.

Firstly, a central position may provide the focal firm with the benefits of resource exchange. Interorganisational exchange relationships provide firms with an opportunity to resolve the problem of having to accumulate resources for a long time prior to gaining any competitive advantage (Ahuja, 2000a). Through interorganisational relationships, firms can obtain access to resources that create competitive advantage. Efficient resource exchange using appropriate vehicles, e.g. alliances, has been shown to yield several benefits to organisations (Baum and Oliver, 1991; Baum *et al.*, 2000; Hagedoorn and Schakenraad, 1994; Mitchell and Singh, 1996; Powell *et al.*, 1996; Miner *et al.*, 1990).

If a venture capital firm is in a central position in the syndication network, it has frequent connections to several other venture capitalists that can potentially exchange resources with it. The large number of connections increases the probability that the firm can find syndicate partners that possess complementary resources. Thus, centrality should improve the efficiency of resource exchange through the collaborative linkages. Typical

resources that can be exchanged in venture capital syndication relationships are money, investment evaluation resources, and 'value-adding' resources that venture capitalists use to steer the portfolio companies in the right direction. In practice, exchange partners provide the focal venture capital firm with limited access to their human resources, including general partners and junior employees, and with access to external resources in their own co-operative network, such as investment banks, law firms, auditors, consultants, and potential portfolio company clients. If the focal venture capital firm can utilise this additional resource base, it may be able to improve its performance in the marketplace.

The second potential benefit from a central network position is the access to the flow of deal information in the network. It is known that venture capitalists frequently share information on prospective investment targets in their syndication network (Bygrave, 1987; Sorenson and Stuart 2001). The more central the position held by a venture capital firm in the co-operative network, the more information flows through the firm. Key firms act as central nodes in the network, and observe most of the so-called deal flow. If a venture capitalist has a large variety of prospective portfolio companies to choose from, it is more likely that the companies ultimately chosen in the portfolio will be of good quality than if the venture capitalist had only a small variety of potential targets. Venture capital firms that are able to observe and screen a wide variety of targets within the fund's investment period are better off than firms with less deal flow.

Thirdly, central position gives the focal firm a high status. Status acts as a indicator of the quality of the companies associated with the focal firm (Benjamin and Podolny, 1999). Status has been found to be an important factor in certifying the quality of portfolio companies under uncertainty and asymmetric information (Carter and Manaster, 1990). As a result, central and high-status venture capital firms should be able to overperform peripheral firms in the exit markets for their investments.

Venture capital firms cannot, however, immediately capitalise on the potential benefits stemming from their position. Rather, we expect the potential performance improvements to be realised with a time lag. A time lag is probable because the gains from a central position can be observed in the form of tangible performance only after the actions enabled by the central position have taken place and yielded an outcome. Improvements in selection and value-adding capabilities will affect the venture capitalist's observable performance only after the investments have been realised. This typically takes several years after the investment; the average period from a venture capital investment to exit is approximately five years (Sahlman, 1990). Similarly, the social structural gains from position, such as informational advantages and status benefits, are likely to yield tangible results only after a number of years. Consequently, we expect that the benefits of position allow central venture capital firms to achieve above-average performance, but with a time lag:

Hypothesis 1: *The centrality of a venture capital firm's position in the syndication network is positively related to the subsequent performance of the firm.*

While the hypothesised relationship between past position and current performance seems clear-cut, both past performance and past position can be argued to be the determinants of current network position. On one hand, the resource-based argumentation suggests that successful firms attract other firms to engage in exchange relationships with them. An excellent prior track record of generating high returns or successfully realising investments make a certain venture capitalist an attractive co-investment partner to other investors because of signalling benefits. The resource-based view of network formation argues that firms assess the quality of the potential partners' resources by acquiring information on their current observable resource endowments, or by examining the past performance of the partners' actions (Baum *et al.*, 2000). An observable track record is a major factor in reducing the asymmetry of information between the focal firm and its potential exchange partners. Information asymmetry exists because the focal firm has superior knowledge of the quality of its own resource base compared to the potential exchange partners. Additionally, the focal firm has an incentive to overstate its quality in order to establish beneficial exchange relationships. Rational partners recognise this incentive, and become more cautious about forming a relationship unless the focal firm can signal its quality in a reliable way. Signalling reduces the partners' risk of adverse selection, i.e. the risk of establishing a relationship of inferior quality (Akerlof, 1970; Spence, 1974). Thus, signalling reduces the barriers to establishing a relationship, and accumulated reputation represents a key factor for signalling quality. As a result, other firms would increase their willingness to collaborate with the focal firm if it has performed well. This, in turn, would lead to an increase in position centrality.

As in the case of the relationship between current performance and prior position in the network, we expect there to be a time lag from the realisation of good performance to the improvement of position in the venture capital syndication network. However, this time lag should be shorter than that between position centrality and subsequent performance because of social recognition. Other firms should recognise the above-average performance of their potential exchange partners without major delays, since the track record of a venture capital firm is typically formed of successful investment exits. Good exits are most often publicised, and the reputation of well-performing firms is distributed rapidly in the venture capital community. It is therefore likely that if the good performance of a venture capital firm increases the willingness of other firms to exchange with the focal firm, the exchanges will be realised without major lags after the exceptional performance has been observed.

The resource-based argumentation of network formation leads to the following hypothesis:

Hypothesis 2a: *The performance of a venture capital firm is positively related to the subsequent centrality of its position in the syndication network.*

On the other hand, the social structural view stresses that prior exchanges are the major determinant of future exchanges (Granovetter, 1985; Gulati, 1995). Network dyads are most likely formed between actors that have previously co-operated with each other, because prior exchanges can significantly reduce the quality uncertainty that the exchange partners have over each other's resources, and because institutionalised relationships increase the efficiency of new exchanges (Ahuja, 2000a). Venture capital firms have also been observed to reciprocate their past syndicate partners by inviting them to participate new deals (Bygrave, 1988).

Status effects constitute another social mechanism that contributes to the stability of prior positions. Economic actors are willing to form exchange relationships with high-status firms because an association with high-status exchange partners may enhance the level of attention paid on the focal actor's endeavours. A firm's reputation and its ability to establish new linkages are likely to improve when it co-operates with high-status exchange partners (Stuart, 1998). Network and institutional theorists also agree that an economic actor's performance in its marketplace is affected by the status levels of its close associates (Baum and Oliver, 1991; Podolny 1994). Firms associated with high-status partners are likely to be considered of higher status than firms without such association. Status legitimises their resources, decreases the problems from information asymmetry, and attracts further partners. Thus, the more central a position a venture capital firm has, the more willing should other VCs be to form relationships with it, and the better should these partners be positioned in the syndication network. Such status effects may reinforce the position centrality of the most central firms in the syndication network.

The social structural view suggests a competing hypothesis on the determinant of position centrality in venture capital syndication networks:

Hypothesis 2b: *The centrality of a venture capital firm's position in the syndication network is positively related to the subsequent centrality of its position.*

3 DATA AND METHODS

3.1 Data

While most of the previous research on venture capital syndication networks has focused on the creation of dyads between firms (Bygrave, 1987; Bygrave, 1988; Anand and Piskorski, 2001), the focus of this paper is the venture capital firm. More precisely, we analyse a time series of yearly observations from each venture capital firm in our sample. The focus of the analysis is the interrelation between a firm's performance and its position in the syndication network.

Our sample consists of the 100 leading private U.S. venture capital organisations which we identify on the basis of the number of portfolio companies in which the firms had invested by the end of the year 2000, and the venture capital investments made by these firms between 1986 and 2000. Sampling from the leading firms in the industry was necessary to ensure the availability and reliability of data. Previous studies on networks and alliances have used a similar strategy (Gulati, 1995; Ahuja, 2000a). In spite of the focus on the top 100 firms, our sample still provides considerable variation regarding the variables examined in the analyses.

The venture capital investment data of this paper was obtained from the Securities Data Corporation's Venture Economics database. This source has also been used in previous venture capital research (e.g. Bygrave, 1987; Lerner, 1994; Gompers, 1995; Gompers and Lerner, 1998). Venture Economics has gathered venture capital investment data since the 1970s using the annual reports of venture capital funds, personal contacts to funds' personnel, initial public offering prospectuses, and acquisitions announced in the media. The database contains information on over 150,000 private equity investments (one financing round consists of several single investments), and it is widely recognised as a leading source of U.S. venture capital investment data.

Supplementary data were gathered from the back issues of *Pratt's Guide to Venture Capital Sources*, which lists the general partners, key personnel, and a variety of other parameters for most of the U.S. venture capital firms each year. The most relevant records for our study are the lists of general partners. For each year that a certain firm has been included in the publication, these data are reported consistently with names and positions. Using data from Pratt's Guide, we tracked the total number of partners and their names in each venture capital firm each year. We classified personnel as partners if their position title included one of the terms 'partner', 'vice president' or 'managing director'. To further ensure the validity of the general partner data in Pratt's Guide, we collected the current résumés of 28% of the partners of our sample firms and reviewed their career years in each venture partnership. We then compared the Pratt's Guide listings of partners to the sub-sample of résumés without observing significant inconsistencies between these two sources.

The sample of investments was selected from the universe of all venture capital investments using multiple criteria. Firstly, we restricted the data set to contain only U.S. venture capitalists and investments. We restricted our sample to those U.S. venture capital partnerships that Venture Economics classifies as "Independent private partnerships". Thus, we did not take into account investment bank affiliates, corporate investors, endowments, individuals, or other private equity investors. Secondly, we examined only investments in U.S. portfolio companies. Finally, we limited the sample to investments that are standard venture capital investments. We implemented this by removing records that Venture Economics classifies as "leveraged buyout", "secondary

purchase", "open market purchase", "private investment in public company" or "turnaround".

As our analysis sample contains only the 100 U.S. largest venture capital partnerships, we cannot always observe all the syndication partners of a given firm because some of the partners may not figure among the 100 largest firms. This bias could lead to a situation in which the syndication partners of some firms were systematically left out. Therefore, we extended the original sample of 100 companies to include the 160 largest venture capital investors in order to check the robustness of our position centrality measures, yet keeping the practical problem of the exponentially growing effort required to construct the syndication matrix under control. In fact, we can observe on average 44% of the firms that invested in each company, while the investments by the 160 largest firms capture over 90% of all the portfolio companies in the Venture Economics database between 1986 and 2000. However, measuring centralities for the 100 sample firms from the syndication network of the 100 largest venture capital firms produced qualitatively equal results to those we obtained by measuring the variables from the syndication network of the 160 largest firms. The results indicate that the choice of the sample does not generate systematic errors in our centrality measures. Altogether, the data set includes 54,700 investments in 10,057 portfolio companies in the years 1986 – 2000.

3.2 Variables

3.2.1 Performance

In principle, venture capital firms are most successful when they maximise the value of their shareholdings. This results directly from the definition of a venture capital firm. Venture capital firms are investment management companies that raise funds from limited partners, including institutional investors, corporations, and wealthy individuals. VCs invest these funds in equity stakes in unquoted companies, actively participate in the development of these companies, and harvest their investments typically within 3-7 years in a public offering or a trade sale. In these 'exits', venture capital firms either distribute the shares of the portfolio companies or pay back cash to the limited partners. The management company, i.e. the general partners, is rewarded with a 20-25% stake of the returns to the limited partners in addition to a 1.5-3% annual managing fee on the capital invested in the venture capital fund (Gompers and Lerner, 1999a). The general partners receive the highest compensation when they maximise the return on capital invested. Thus, the wealth of all parties is maximised when the value of the venture capital firm's shareholdings is maximised.

Measuring the performance of venture capital firms is difficult for an outside observer because the lack of public information. Considering the maximisation of the venture capital firm's shareholdings, the internal rate of return (IRR) of the firm's funds would be the most interesting performance measure, as it illustrates the return on capital invested,

and hence represents the creation of value to the limited and general partners. However, these numbers are regarded as trade secrets, and reliable, industry-wide IRR figures on individual funds are not available.

However, comparing successful exits across venture capital firms provides a reasonable measure of performance. Megginson and Weiss (1991) used the market share of portfolio company initial public offerings as a measure of venture capitalist track record. Similarly, we choose to use the yearly market share of initial public offerings to measure the relative performance of venture capitalists. IPO track record is a quantifiable performance measure for venture capitalists and offers three clear advantages. Firstly, the valuations of the portfolio companies are ultimately formed in a competitive market in the IPO, and hence the IPO provides a reliable view of the market value of these companies. Secondly, the largest valuations and returns to venture capitalists are most often realised in IPOs (Bygrave and Timmons, 1992). Although only a fraction of venture capital investments reach the IPO, most of the total value to the investors is created in these exits (Bygrave and Timmons, 1992; Gompers and Lerner, 1999b). Thus, we can consider the IPO as the preferred exit vehicle for most venture capital firms. Thirdly, an IPO is a publicised event in the market, conveying information that has a direct reputational effect for the focal venture capital firm, as an IPO indicates that the firm has been able to make a very successful investment. Thus, we argue that the value-weighted market share of initial public offerings is a valid measure for the success of a venture capital firm relative to its peers. A value-weighted share of IPOs captures the ability to generate initial public offerings relative to peer investors, and also rewards for value creation in addition to the mere frequency of portfolio company IPOs.

We obtained the initial public offering (IPO) valuation data from the Securities Data Corporation's (SDC) New Issues database. SDC New Issues is a source of IPO data that records up to 250 characteristics of the issuer, the underwriter syndicate, and market characteristics at the time of the issue. We recorded the final offer price and the number of shares outstanding after the offer to determine the IPO market value of the firm. Since some inconsistencies in the number of shares outstanding after the offer were encountered in the SDC data, the initial public offering related data were also cross-checked by comparing them to the data from IPO prospectuses obtained from the Securities and Exchange Commission's Edgar database. To ensure validity, two researchers independently recorded the necessary prospectus data, and compared the sets to each other and the SDC data. Ambiguous cases were then re-checked and corrected using the prospectus information.

3.2.2 Network centrality

Venture capital firms are connected to each other both through informal and personal ties on the general partner level and through formal or contractual ties on the firm level. These dyadic connections of venture capitalists can be combined to form a network.

Using a network to describe the relationships, not only includes the original information about the dyadic relationships but it also captures the overall structure of relations within a set of venture capital firms.

The centrality of a firm is a network measure that illustrates the focal firm's position in the network relative to its exchange partners. Essentially, the more a firm has connections to others, the more central it is. Additionally, the centralities of the firms the focal firm is connected to affect the focal firm's centrality. The more central firms the focal firm is connected to, the higher its centrality. Thus, centrality is positively related both to the number of connections and the centralities of the firm's exchange partners.

We interpret the syndication relationship as a network tie between two venture capital firms. In order to invest in the same venture, the venture capital firms need to co-operate closely in selecting the venture, in structuring the deal, and in adding value to the company in the long run. Hence, a syndication relationship is a strong indicator of the degree of co-operation between the two venture capital firms. Although there certainly exists a range of other types of relationships between VCs, syndication offers a comprehensive indicator of intra-industry co-operation in investment activities.

The strictest definition of syndication requires that two or more venture capitalists invest in the same venture in the same round of financing. However, the Venture Economics data impose certain restrictions for measuring syndication according to the strictest definition. The records in the Venture Economics database occasionally overstate the number of financing rounds because of staged distributions of funds and variations in the reported dates of the source data (Lerner, 1994; Gompers and Lerner, 1999b). As our focus is the network of venture capital firms, we can alleviate the problem of unmatched records by broadening the concept of syndication from co-investment in the same financing round to co-investment in the same company within a limited period. We choose to define a syndication relationship as the event of two venture capital firms investing in the same venture within a year. Because our unit of analysis is the firm-year observation, our definition of a syndication relationship should have no unexpected impacts on the final results.

To establish the centrality scores for each venture capital firm, we use Bonacich's (1987) centrality measure $c_i(\alpha,\beta)$ defined as

$$c_i(\alpha,\beta) = \sum_j (\alpha + \beta c_j) R_{ij}$$

where R_{ij} is an element of the relational matrix R, and each element of R is the number of companies in which the firms i and j have invested together. β is the degree to which the centrality of i is function of the centralities of other firms. β can be interpreted as the radius of the influence of i. If we do not expect the syndication relationships of j to directly benefit i, β should be small. We follow the practice of earlier studies and set β

equal to three quarters of the reciprocal of the largest eigenvalue of R (Podolny, 1993; Sorenson and Stuart, 2001).

In our sample, venture capital firms enter the sample each year as they are founded, apart from firms that were founded before 1986. Thus, the structure of our syndication network changes yearly. As a result, a firm's centrality may change from year to year even if its syndication relationships remain unchanged. To standardise the centrality measure across years, we choose α so that the sum of squared centralities equals the number of firms in the network (Bonacich, 1987). Thus,

$$\sum_i c_i(\alpha,\beta)^2 = n .$$

3.2.3 Firm general partners

Our third dependent variable is the number of general partners in the venture capital firm. While our primary operationalisation of firm performance is the market share of portfolio company IPOs, we also measure firm performance with the number of general partners in each firm over time to ensure the robustness of the results and to better understand how network positions are acquired and retained. We assume that successful firms are able to increase the number of general partners, while unsuccessful firms would tend to do the opposite. Another reason to examine the number of general partners over time in each firm is that changes in the number of general partners also act as indicators of changes in the network of relationships the firm has. An incoming additional partner usually brings in a number of new interorganisational relationships through his personal contacts, and a leaving partner often makes several relationships disappear. If this is the case, we will observe changes in the number of general partners to affect the position of the firm.

The number of partners each year is taken from our combination of the records from *Pratt's Guide to Venture Capital Sources* and the résumés of the general partner sub-sample. We recognise that the records from Pratt's Guides represent the situation of the year previous to the year of publication, and use each year's Pratt's Guide data for the previous year entries. We further assume that the number of general partners during a single calendar year remains constant. In the rare cases in which general partner data are unavailable from both sources for a certain year, we use the data of the previous year.

3.3 Control variables

Resources and firm size. The main resources a venture capital company needs are the capital to be invested, supply of potential investment targets, and the human resources managing the firm and its investments (Bygrave, 1987). The scarcity or availability of resources is likely to have a significant effect on the propensity of the firm to syndicate, and thus internal resources need to be controlled for in the models, apart from the number of general partners that we treat as an independent variable.

To capture the overall size of the firm, we control for the market share of investments, calculated as the number of new companies in which the firm invested each year divided by the number of all new companies receiving venture capital financing in the sample that year.

When raising funds, venture capitalists negotiate capital commitments from limited partners, and invest them gradually over a few years into promising target companies. The sum of these commitments in a firm is referred to as 'capital under management'. We calculate the sum of the non-expired venture capital funds, and exclude funds that are raised for investments in e.g. buyouts. We include only funds that Venture Economics classifies as 'venture capital' in our sample. We further assume the expiration of a fund to take place within ten years of the vintage year, which Sahlman (1990) found to be the case in 72% of the funds in his sample. Thus, the total size of a fund is calculated as part of capital under management for the ten years after its raising was completed.

Location. A wide and continuous supply of investment targets (deal flow) is generally regarded as an important success factor venture capital investing (Bygrave, 1987; Sahlman, 1990). However, we are unable to observe the deal flow that a given venture capital firm faces. The number and quality of business proposals are guarded trade secrets, and there are no records of the deal flow. Following the convention of earlier research (e.g., Gompers and Lerner, 2000), we control for differences in the supply of investment targets using location variables. In our sample, 48% of investments were made in companies in California, 13.5% in Massachusetts, and 4.8% in Texas. VCs located in California made 40% of all investments, VCs in Massachusetts 21%, and those in New York 8%. Respectively, 53 VCs are located in California, 33 in Massachusetts and 15 in New York. We use dummy variables to indicate whether the VC firm is located in California, Massachusetts or another state.

Venture capital firm age. The age of a venture capital firm may have significant impacts on its operations. The older the firm, the more contacts, experience, and prominence it has. In addition, the younger the firm, the more it tries to establish a reputation by opportunistically striving towards successful exits. This is a phenomenon called 'grandstanding' (Gompers, 1996). We thus control for age effects. We calculate the age of each firm in our sample on the basis of the founding dates in the Venture Economics database. We cross-checked the validity of these records using the back issues of Pratt's Guides, and overrode Venture Economics data in case of conflict. In some rare cases, we found that Venture Economics had allocated venture capital investments to the firm prior to the reported founding date. In these cases, we set the company founding year as the year of the first investment recorded for the firm in the Venture Economics database.

Investment stage mix of investments. The stage of development of a venture affects both the risk and the expected time-to-exit of the venture capital investments in the venture. In addition, a firm investing exclusively in later-stage companies is likely to be involved in

proportionally more IPOs than one investing in early-stage companies. We calculate the percentage of investments in early-stage, expansion stage and later-stage ventures for each firm each year according to Venture Economics classifications.

Industry mix of investments. We also control for potential industry effects. We use Venture Economics' classification of investments into the following industry sectors: medical/health, biotechnology, communications, computer hardware, computer software, semiconductors/electronics, Internet communications, Internet/computer related, and non-high-technology ventures as recorded by Venture Economics. We calculate the percentage of investments in each of these industry segments for each firm and each year.

Time-dependency. As our sample is a time series of cross-sections, it is necessary to control for differences between sample years. In all regressions, we include dummy variables for the sample years.

3.4 Methods

The time series – cross-sectional nature of our data set not only allows us to test the existence of the hypothesised relationships, but also enables testing of causality. More specifically, the data enables us to examine *Granger causality*. Variable X is said to Granger-cause Y if the lagged values of X are significant predictors of Y when Y is regressed on its own lagged values (Granger, 1969). By first regressing current performance on prior performance and prior position centrality, and then symmetrically regressing current position centrality on prior performance and prior position centrality, we can test whether centrality is the major determinant of performance or whether performance determines centrality. In addition to running regressions on the measures of performance and position, we supplement the analysis by conducting the Granger causality tests using first differences of the variables. This approach has the advantage of alleviating the impact of potentially high zero-order correlations between the lagged values of relatively static variables, such as position centrality or the number of general partners.

Because our analysis needs to tackle an unbalanced time series – cross-sectional panel data set of firm-year observations, straightforward statistical methods that assume there to be no heteroskedasticity, unobserved heterogeneity, or first-order autocorrelation, are inapplicable. While we run also conventional OLS regressions for comparison, we present only the results of the theoretically more robust time-series cross-sectional generalised least squares (GLS) regressions with fixed-effects specifications. This approach simultaneously controls for potential first-order autocorrelation across the subsequent observations of the same firm and heteroskedasticity across the observations of the different firms, and utilises robust maximum-likelihood estimates for the model coefficients. While pooled ordinary least squares models provide qualitatively similar

results, the statistical approach adopted in this study gives a more realistic view of the magnitude, standard errors, and significance of the individual regression coefficients.

To control for unobserved heterogeneity in our sample, we choose to utilise the fixed firm effects approach. A fixed-effects model is appropriate when inferences are made conditional to the sample, whereas a random-effects model should be chosen when inferences are made for the entire population (Hsiao, 1986). Since our position measures are conditional to the sample, the first approach was selected as more appropriate. However, we found the differences in the results to be marginal if random-effects models are used.

4 RESULTS

4.1 Descriptive statistics

Table 1 reports the descriptive statistics and correlations for the sample of 1333 yearly observations on the 100 venture capital firms in the sample. The average age of the firms is 17.7 years. On average, the firms have 5.8 general partners, and the average amount of capital under management is 255 million dollars. The amount of capital under management varies more than the number of partners indicating differences in investment focus across venture capital firms and differences between sample years due to the enormous growth of the venture capital industry in the 1990s. The industry mix of investments is relatively even, and most of the industry share averages are approximately 8%-14%. Exceptions are the Internet communications and the software sector, which represent the 'boom' investment sector of the 1990s, and the youngest and thus the smallest groups of the sample, respectively. The average portfolio includes 33% early-stage firms, 39% expansion-stage firms, and 24% late-stage firms.

The value-weighted market shares of initial public offerings vary significantly among the firms. At maximum, a single firm has been able to participate in 11% of the sample firms' portfolio company IPOs in a specific year. Bonacich's centrality score statistics reveal that the average centrality score is only 0.81. An interpretation of centrality score states that score of one means that firm does not have unusually large or small centrality (Bonacich, 1987). Hence there is a group of firms that have relatively high centrality scores, but the majority of the sample firms form the syndication network around these central firms. The skewness of the distribution is similar to prior studies (Podolny, 2001).

The pairwise correlations listed in Table 1 deserve a methodological comment. On the basis of the fact that especially the yearly centrality scores and the numbers of general partners are positively correlated with their own lagged values, we paid specific attention to controlling for multicollinearity in further analyses. High correlations among the independent variables may cause the regression coefficients of the correlated independent variables to appear insignificant because the variables mask each others'

explanatory power. The usual statistical thresholds for a multicollinearity problem are a correlation coefficient of 0.8 between any two independent variables, a variance inflation factor over 10, or a tolerance score below 0.1. The first threshold is not exceeded in our data set, as the maximum correlation among independent variables is 0.79 (between centrality at *t* and centrality at *t* – 1). However, generalised least squares regression models that we utilise in further analyses do not allow the calculation of variance inflation factors or tolerances. To ensure that multicollinearity does not distort our results, we ran identical ordinary least squares regressions for all the models presented in this paper, and calculated VIF and tolerance scores for them. The results indicated that multicollinearity is not a problem. Furthermore, the first differences analysis helps to alleviate the problem of high zero-order correlations between some relatively static variables and their own lagged values.

Table 1 Descriptive statistics and correlations (1333 firm-year observations).

	Minimum	Maximum	Mean	Std. dev.
Bonacich's centrality	0.00	4.49	0.81	0.85
Value-weighted market share of initial public offerings (%)	0.0	11	1.0	1.1
Venture capital firm age	0.5	65	17.7	10.5
Market share of investments (%)	0.0	8.3	1.0	0.8
Number of general partners	1	22	5.8	3.0
Capital under management (BUSD)	0.1	4.0	0.25	0.36
Share of investments to medical (%)	0	100	13	16
Share of investments to biotech (%)	0	100	8	13
Share of investments to software (%)	0	100	20	18
Share of investments to hardware (%)	0	100	9	12
Share of investments to Internet, computer-related (%)	0	100	6	12
Share of investments to semiconductors (%)	0	100	8	12
Share of investments to communications (%)	0	100	15	16
Share of investments to Internet communications (%)	0	56	3	6
Share of investments to non-high-technology (%)	0	100	14	17
Share of investments to early stage ventures (%)	0	100	33	21
Share of investments to expansion stage ventures (%)	0	100	39	21
Share of investments to later stage ventures (%)	0	100	24	19

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Centrality, t	1.00													
2	Centrality, t-1	0.79	1.00												
3	Centrality, t-5	0.62	0.68	1.00											
4	IPO market share, t	0.44	0.47	0.49	1.00										
5	IPO market share, t-1	0.37	0.40	0.47	0.57	1.00									
6	IPO market share, t-5	0.27	0.29	0.41	0.45	0.44	1.00								
7	No. of partners, t	0.35	0.33	0.28	0.39	0.39	0.30	1.00							
8	No. of partners, t-1	0.33	0.34	0.30	0.42	0.39	0.33	0.79	1.00						
9	No. of partners, t-5	0.22	0.24	0.34	0.38	0.37	0.34	0.64	0.70	1.00					
10	ΔCentrality, t-1…t	0.27	-0.26	-0.11	-0.06	-0.06	-0.04	0.04	-0.02	-0.04	1.00				
11	ΔCentrality, t-2…t-1	0.11	0.29	-0.07	-0.04	-0.06	-0.04	0.02	0.03	-0.06	-0.35	1.00			
12	ΔCentrality, t-6…t-5	0.14	0.12	-0.29	0.02	0.00	-0.05	0.01	0.04	-0.06	0.03	-0.01	1.00		
13	ΔIPO share, t-1…t	0.07	0.06	0.01	0.28	-0.31	0.00	0.01	0.00	-0.01	0.02	0.04	0.03	1.00	
14	ΔIPO share, t-2…t-1	0.05	0.06	0.02	0.01	0.31	-0.01	0.02	0.01	-0.02	-0.01	0.01	-0.01	-0.43	1.00
15	ΔIPO share, t-6…t-5	0.02	0.03	0.03	0.00	0.01	-0.37	0.02	0.01	-0.01	-0.01	0.00	-0.01	-0.01	0.04
16	ΔPartners, t-1…t	0.06	0.00	-0.02	-0.03	0.01	-0.04	0.30	-0.16	-0.09	0.12	-0.02	-0.06	0.01	0.03
17	ΔPartners, t-2…t-1	0.04	0.05	-0.06	-0.04	-0.01	-0.02	0.18	0.20	-0.11	-0.01	0.11	0.07	-0.08	0.06
18	ΔPartners, t-6…t-5	0.07	0.08	-0.01	0.04	0.03	0.01	0.11	0.11	-0.23	-0.03	0.07	0.06	0.01	0.03
19	Market share of invs.	0.59	0.62	0.51	0.60	0.53	0.38	0.43	0.44	0.36	-0.05	0.07	0.06	0.04	0.05
20	Capital under mgmt	0.36	0.35	0.30	0.37	0.38	0.36	0.51	0.46	0.38	0.01	0.02	0.02	0.00	0.02
21	Firm age	-0.01	0.00	0.10	0.08	0.07	0.17	0.21	0.21	0.32	-0.02	-0.02	-0.09	-0.01	-0.05

Table 1 (continued)

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
22	California	0.44	0.45	0.36	0.18	0.16	0.10	0.03	0.02	-0.06	0.00	0.02	0.06	0.01	0.03
23	Massachusetts	-0.05	-0.06	-0.06	0.02	0.03	0.03	0.11	0.12	0.15	0.01	0.01	0.00	0.00	-0.02
24	Medical %	0.05	0.08	0.06	0.04	0.07	0.05	0.01	0.05	0.08	-0.05	0.06	0.04	-0.06	-0.01
25	Biotech %	0.05	0.09	0.01	0.04	0.04	0.02	-0.09	-0.05	-0.02	-0.07	0.03	0.03	-0.03	-0.04
26	Software %	0.25	0.26	0.15	0.11	0.07	0.08	0.14	0.12	0.02	-0.02	0.08	0.10	0.04	-0.01
27	Hardware %	0.07	0.11	0.12	0.06	0.07	0.02	-0.09	-0.07	-0.06	-0.08	0.03	0.02	0.00	-0.01
28	Internet/Computer %	0.19	0.19	0.09	0.01	0.01	0.04	0.16	0.08	0.02	0.00	0.03	0.02	0.00	0.06
29	Semiconductors %	0.04	0.10	0.07	0.05	0.05	0.00	0.04	0.05	0.07	-0.12	0.07	0.04	0.04	-0.03
30	Communications %	0.15	0.13	0.08	0.03	0.01	0.04	0.02	0.03	0.01	0.04	0.03	-0.06	0.03	0.03
31	Internet/Communic. %	0.17	0.18	0.06	0.01	-0.01	0.02	0.19	0.14	0.09	-0.01	0.08	0.07	0.02	0.01
32	Early stage %	0.36	0.31	0.19	0.08	0.08	0.04	0.04	0.02	-0.06	0.08	0.14	0.07	0.02	-0.04
33	Later stage %	-0.02	0.10	0.08	0.03	0.04	0.04	0.01	0.04	0.13	-0.22	0.04	-0.01	-0.05	0.04

		15	16	17	18	19	20	21	22	23	24	25	26	27	28
15	ΔIPO share, t-6…t-5	1.00													
16	ΔPartners, t-1…t	0.02	1.00												
17	ΔPartners, t-2…t-1	0.01	-0.03	1.00											
18	ΔPartners, t-6…t-5	0.00	0.02	-0.08	1.00										
19	Market share of invs.	0.02	0.00	0.00	0.06	1.00									
20	Capital under mgmt	0.01	0.14	0.04	0.03	0.49	1.00								
21	Firm age	-0.05	0.00	-0.02	-0.09	0.03	0.17	1.00							
22	California	0.03	0.03	0.03	0.05	0.21	0.11	-0.12	1.00						
23	Massachusetts	-0.01	-0.01	0.00	-0.02	-0.07	0.02	0.08	-0.39	1.00					
24	Medical %	0.00	-0.09	-0.02	-0.03	0.09	0.00	-0.07	0.00	-0.11	1.00				
25	Biotech %	0.02	-0.10	-0.01	-0.01	0.04	-0.07	0.03	-0.04	0.04	0.10	1.00			
26	Software %	0.00	0.04	0.06	0.03	0.11	0.09	-0.11	0.16	0.11	-0.26	-0.22	1.00		
27	Hardware %	0.03	-0.06	-0.04	0.01	0.00	-0.09	-0.09	0.11	0.09	-0.15	-0.09	0.03	1.00	
28	Internet/Computer %	-0.01	0.19	0.09	0.04	0.06	0.37	0.09	0.15	-0.03	-0.12	-0.19	0.03	-0.14	1.00
29	Semiconductors %	0.02	-0.03	0.00	0.02	0.02	-0.02	0.02	0.06	0.00	-0.14	-0.06	-0.11	0.04	-0.10
30	Communications %	0.01	-0.03	-0.01	0.05	0.07	0.04	0.00	0.03	0.01	-0.19	-0.12	-0.09	-0.09	-0.07
31	Internet/Communic. %	0.02	0.11	0.06	0.00	0.08	0.24	0.12	0.12	-0.06	-0.10	-0.16	0.03	-0.11	0.37
32	Early stage %	0.10	0.04	0.06	0.05	0.19	0.05	0.00	0.23	-0.05	0.09	0.15	0.15	0.11	0.02
33	Later stage %	-0.03	-0.06	-0.03	0.01	0.06	0.00	-0.01	-0.07	0.06	0.05	0.06	0.03	0.15	-0.10

		29	30	31	32	33
29	Semiconductors %	1.00				
30	Communications %	-0.02	1.00			
31	Internet/Communic. %	-0.10	0.07	1.00		
32	Early stage %	0.00	0.02	0.05	1.00	
33	Later stage %	0.15	0.04	-0.04	-0.33	1.00

Table 2 illustrates the close relationship between performance in the IPO market and position centrality in the syndication network. Panels A and B contain the 25 top firms in the sample in terms of the value-weighted IPO market share and position centrality, respectively. The IPO market share for a given year is defined as the sum of the offer values of the firm's portfolio company IPOs divided by the total offer value of all sample IPOs in the same year. Using value-weighted market shares instead of equal-weighted ones also allows us to take into account the amount of value created in the exits instead of only the relative number of successful exits.

Panel A shows that the top 25 companies have a combined value-weighted IPO market share of 45.9 %. Many of the VC firms on the list appear to be partnerships that are regarded as prestigious in the practitioner community and publications. The list also demonstrates that portfolio company IPOs are substantially concentrated to a sub-section of the sample firms. However, it is worth noting that several VC firms may have

participated the same portfolio company IPOs because of the syndication of investments. Hence the companies with the largest market shares of investments are presumably involved in relatively many IPOs as well. We will return to controlling for this effect in the regression models.

To illustrate the hypothesised relationship between network centrality and the IPO market share of the firms, Panel B presents the average of Bonacich's centrality measure for the top 25 companies in the sample using the same two time spans. Companies that appear in both panels are highlighted. The fact that 18 firms out of 25 appear in both Panel A and Panel B suggests that there is a positive relationship between the venture capital firm's performance and its centrality in the syndication network. However, the table does not yet reveal which of the phenomena – network centrality or performance – is the dominant factor reinforcing the other.

4.2 Basic Granger causality tests

To address this question and the hypotheses, we construct six different distributed lag fixed effects regression models. Table 3 provides the results for the GLS models on the effect of position centrality in the syndication network on subsequent performance in the IPO market and the number of general partners, and the effect of the performance and partner variables on centrality. In the first two models, the dependent variable is the value-weighted IPO market share of the venture capital firm each year. In the third and fourth models, the dependent variable is the number of general partners in the VC firm each year. In the two rightmost models, the dependent variable is position centrality. The regression coefficients are presented together with the respective *z*-statistics. We also include year dummies and controls on the industry composition of the investment portfolio in the analysis although the coefficients are not shown in the table.

Hypothesis 1 suggested that past position centrality in the syndication network is positively related to the subsequent performance of the firm, but with a time lag. The first two models in Table 3 demonstrate that the lags of IPO market share significantly contribute to subsequent share, and that the two-year lagged centrality score is positively and significantly related to the value-weighted IPO market share of the firm in year *t*. The notion "success breeds success" appears to apply to the venture capital setting. However, the relationship between centrality and the number of managing partners is slightly more ambiguous. The two-year lagged centrality score and the five-year lagged score are positively and significantly related to the number of managing partners in year *t*, but the four-year lagged centrality score has a very significant negative impact on the same variable. Instead, the lagged values of the number of general partners tend to determine the subsequent values of the variable. The number of partners appears to be relatively stable.

Table 2 IPO market share and position centrality

Panel A presents the value-weighted market share of portfolio company initial public offerings for the top 25 companies in the sample. The venture capital firms include only independent U.S. partnerships that invest in the traditional venture capital stages of development. The IPO market share in a given year is defined as (offer value of firm's portfolio company IPOs in the given year) / (offer value of all sample IPOs in the given year). Note that several VC firms may have participated in the same IPOs. Panel B presents Bonacich's centrality in the syndication network for the top 25 companies.

Panel A: Value-weighted market share of sample venture-backed initial public offerings

	Venture capital firm name	Average 1986-2000	Average 1995-2000	Firm appears in Panel B
1	Kleiner Perkins Caufield & Byers	4.51 %	5.90 %	Yes
2	New Enterprise Associates	2.72 %	2.93 %	Yes
3	Sequoia Capital	2.34 %	2.69 %	Yes
4	Accel Partners	1.58 %	2.49 %	Yes
5	Norwest Venture Partners	1.14 %	2.32 %	Yes
6	Bessemer Venture Partners	1.44 %	2.10 %	Yes
7	U.S. Venture Partners	1.54 %	1.87 %	Yes
8	Benchmark Capital	0.72 %	1.80 %	
9	Mayfield	1.80 %	1.77 %	Yes
10	HarbourVest Partners, LLC.	1.75 %	1.69 %	
11	Jafco American Ventures, Inc.	0.65 %	1.64 %	Yes
12	Oak Investment Partners	1.73 %	1.56 %	Yes
13	Institutional Venture Partners	1.82 %	1.54 %	Yes
14	Robertson Stephens & Company, LLC	1.89 %	1.49 %	
15	Matrix Partners	1.12 %	1.47 %	Yes
16	Mohr, Davidow Ventures	0.97 %	1.43 %	Yes
17	Centennial Ventures	2.08 %	1.42 %	
18	Greylock Management Corp.	1.36 %	1.39 %	Yes
19	Summit Partners	1.15 %	1.34 %	
20	Venrock Associates	1.58 %	1.33 %	Yes
21	InterWest Partners	1.51 %	1.30 %	Yes
22	Charles River Ventures	1.16 %	1.18 %	Yes
23	TA Associates, Inc.	2.35 %	1.10 %	
24	Crosspoint Venture Partners	0.65 %	1.08 %	Yes
25	Vanguard Venture Partners	0.75 %	1.07 %	

Panel B: Bonacich's centrality in the syndication network

	Venture capital firm name	Average 1986-2000	Average 1995-2000	Firm appears in Panel A
1	New Enterprise Associates	3.52	3.57	Yes
2	Accel Partners	2.60	3.14	Yes
3	Kleiner Perkins Caufield & Byers	3.14	2.78	Yes
4	Institutional Venture Partners	2.79	2.69	Yes
5	Oak Investment Partners	2.70	2.66	Yes
6	Mayfield	2.71	2.34	Yes
7	Sequoia Capital	2.55	2.02	Yes
8	Bessemer Venture Partners	1.30	1.85	Yes
9	U.S. Venture Partners	2.04	1.85	Yes
10	Norwest Venture Partners	1.19	1.80	Yes
11	Crosspoint Venture Partners	1.05	1.70	Yes
12	Charles River Ventures	1.03	1.68	Yes
13	Venrock Associates	1.48	1.49	Yes
14	Matrix Partners	1.43	1.47	Yes
15	Mohr, Davidow Ventures	1.56	1.37	Yes
16	Greylock Management Corp.	1.09	1.35	Yes
17	Sevin Rosen Management Co.	0.94	1.35	
18	Menlo Ventures	1.29	1.34	
19	Jafco American Ventures, Inc.	0.63	1.33	Yes
20	Delphi Ventures	0.98	1.32	
21	InterWest Partners	1.45	1.27	Yes
22	Burr, Egan, Deleage & Co.	1.33	1.26	
23	Highland Capital Partners	0.70	1.19	
24	Morgenthaler Ventures	1.12	1.16	
25	OneLiberty Ventures	0.80	1.15	

Based on resource-based arguments, Hypothesis 2a proposed that the past performance of a venture capital firm is positively related to its subsequent position centrality in the syndication network. In contrast, Hypothesis 2b suggested that past positions determine subsequent positions. The results of the last two GLS models using centrality as the dependent variable show that the lagged values of centrality represent major determinants of subsequent position centrality in the syndication network. In contrast, the lagged value-weighted IPO market shares are consistently insignificant determinants of current centrality. Similarly, the lagged general partner variables are insignificant or even negative. Prior position, on the other hand, has a notable impact on subsequent position. The centrality scores of the two previous years make the strongest positive contributions to subsequent centrality, while the other lagged centrality scores are insignificant or have a smaller impact.

The results indicate that position centrality consistently Granger-causes performance in the IPO market, and that the impact of centrality is strongly positive. Technically, position centrality also Granger-causes the number of general partners, but the impact is ambiguous with both negative and positive lagged terms. On the contrary, neither the performance in the IPO market nor the number of general partners can be interpreted to Granger-cause position. The results thus suggest unidirectional causality that runs from position to performance in the portfolio company IPO market.

A number of the control variables in Table 3 appear significant in the analysis, but the combined magnitude of the coefficients of the actual independent variables outweighs the magnitude of all the control variables. Of the control variables, the market share of investments is, as expected, positively related to the value-weighted market share of IPOs. Furthermore, a wide resource base in terms of capital under management is positively related to the number of general partners. Investment stage focus also explains some differences in the firms' centralities and IPO market shares.

While the results seem to provide support for the social structural view of interorganisational networks, additional analysis is required to ensure the robustness of the conclusions, and to shed light on the ambiguous relationship between position centrality and the number of general partners. Particular problems may arise from the high zero-order correlations of the general partner and centrality variables with their own lagged values, even though our regressions pass the standard Variance Inflation Factor tests for multicollinearity problems.

Table 3 Granger causality tests of position and performance

Time-series cross-sectional GLS regression with distributed lags and a fixed-effects specification is applied. Regression coefficients and *z*-statistics are presented. Control variables are measured at *t*-1 years. Industry controls are not shown.

	IPO market share, *t*				No. of general partners, *t*				Centrality, *t*			
IPO market share, *t* – 1	.160		.143						-.003			
	(5.73)	***	(5.07)	***					(.46)			
IPO market share, *t* – 2	.077		.069						-.005			
	(2.94)	**	(2.62)	**					(.80)			
IPO market share, *t* – 3	.073		.072						-.001			
	(2.91)	**	(2.80)	**					(.15)			
IPO market share, *t* – 4	.063		.065						-.006			
	(2.52)	**	(2.57)	**					(1.00)			
IPO market share, *t* – 5	.069		.075						.001			
	(3.09)	***	(3.35)	***					(.10)			
No. of general partners, *t* – 1					.860		.862				.101	
					(22.60)	***	(22.63)	***			(1.07)	
No. of general partners, *t* – 2					.024		.019				.135	
					(.54)		(.43)				(1.20)	
No. of general partners, *t* – 3					-.006		-.006				-.058	
					(.18)		(.18)				(.56)	
No. of general partners, *t* – 4					.054		.055				-.225	
					(1.45)	+	(1.47)	+			(2.08)	*
No. of general partners, *t* – 5					-.021		-.022				.051	
					(.78)		(.78)				(.61)	
Centrality, *t* – 1			.056				.002		.652		.593	
			(1.16)				(.27)		(21.91)	***	(16.50)	***
Centrality, *t* – 2			.170				.014		.218		.234	
			(3.50)	***			(1.73)	*	(6.85)	***	(6.10)	***
Centrality, *t* – 3			.006				-.002		-.012		.061	
			(.11)				(.27)		(.37)		(1.65)	*
Centrality, *t* – 4			.024				-.025		.011		.047	
			(.48)				(3.08)	***	(.38)		(1.36)	+
Centrality, *t* – 5			-.067				.013		-.001		-.044	
			(1.61)	+			(1.92)	*	(.07)		(1.66)	*
Mkt share of investments	.739		.496		.017		.015		.048		.053	
	(8.61)	***	(5.07)	***	(2.07)	*	(1.51)		(2.16)	*	(2.17)	*
Capital under mgmt (log)	.000		.000		.000		.000		.000		.000	
	(1.29)		(1.13)		(4.47)	***	(4.58)	***	(2.55)	*	(1.02)	
Firm age (log)	.037		.007		-.010		-.011		-.190		-.038	
	(.60)		(.11)		(.85)		(1.00)		(6.32)	***	(.93)	
Firm located in CA?	.298		.146		-.005		-.004		.132		-.020	
	(3.00)	**	(1.43)		(.36)		(.32)		(3.28)	***	(.41)	
Firm located in MA?	.125		.067		.002		.004		.109		.037	
	(1.25)		(.68)		(.16)		(.33)		(2.36)	*	(.68)	
Early stage %	-.362		-.381		.032		.042		.368		.429	
	(1.92)	+	(2.11)	*	(1.10)		(1.38)		(3.53)	***	(3.60)	***
Later stage %	-.019		-.093		-.036		-.035		-.640		-.434	
	(.09)		(.44)		(1.18)		(1.08)		(5.42)	***	(3.33)	***
(Industry controls not shown)												
Constant	.028		.889		.150		.162		.039		-.483	
	(.15)		(3.20)	***	(3.98)	***	(3.49)	***	(.28)		(2.65)	**
p-value	0.000		0.000		0.000		0.000		0.000		0.000	
Wald χ^2-statistic	839.1		917.8		8130.3		7828.0		7534.0		7153.1	
N	1269		1269		842		842		1269		865	

4.3 Granger causality tests using first differences

To address the issues associated with stable variables in the basic Granger causality tests, we undertake an analysis of first differences. The specifications of the models are identical to Table 3 except that the dependent and independent variables are calculated as the first difference between two consecutive values of the variable. This approach significantly reduces the problems of high zero-order correlation between independent variables, and complements the previous analysis.

The first two models in Table 4 regress the change in IPO market share on its own lags and the lags of the change in position centrality. While the previous changes in IPO market share have a negative contribution on subsequent changes, as expected taken into account typically diminishing marginal returns, the lagged changes in centrality are consistently positively related to performance in the IPO market. Improvements in position tend to breed subsequent performance.

The impact of lagged position changes on the growth in the number of general partners is also positive. The two- and three-year lagged changes in centrality have a significant positive contribution on partner acquisition. Although the four-year lagged change in centrality has a slight negative impact on partner acquisition, the combined magnitude of the regression coefficients is positive and significant.

Changes in centrality are consistently independent of changes in IPO market share. On the contrary, growth in the number of general partners has some positive effects on changes in position centrality. The two- and four-year lagged variables are positive and significant. The relationship between position and the growth in the number of general partners clearer than in the previous analysis.

The results of the first differences analysis confirm and clarify the results of the basic Granger causality tests. Firstly, there is a clear unidirectional causal relationship between position and performance in the IPO market. Position breeds performance. Secondly, there is a *feedback* relationship between position and the number of general partners. A change in centrality has a positive impact on partner growth, but partner growth also has a positive impact on centrality. The acquisition of general partners seems to play a significant role in establishing the firm's position.

Table 4 Granger causality tests of position and performance using first differences

Time-series cross-sectional GLS regression with distributed lags and a fixed-effects specification is applied. Regression coefficients and *z*-statistics are presented. Control variables are measured at *t*. Industry controls are not shown.

	Δ IPO market share, *t*…*t*+1		Δ No. of partners, *t*…*t*+1		Δ Centrality, *t*…*t*+1	
Δ IPO mkt share, *t*-1…*t*	-.623	-.673			.003	
	(22.38) ***	(24.26) ***			(.35)	
Δ IPO mkt share, *t*-2…*t*-1	-.459	-.524			.003	
	(14.87) ***	(16.79) ***			(.34)	
Δ IPO mkt share, *t*-3…*t*-2	-.279	-.338			.003	
	(9.24) ***	(11.08) ***			(.36)	
Δ IPO mkt share, *t*-4…*t*-3	-.133	-.168			-.001	
	(5.45) ***	(6.91) ***			(.11)	
Δ No. of partners, *t*-1…*t*			-.102	-.102		.009
			(2.70) **	(2.71) **		(.10)
Δ No. of partners, *t*-2…*t*-1			-.049	-.058		.171
			(1.89) *	(2.25) *		(1.82) *
Δ No. of partners, *t*-3…*t*-2			-.051	-.061		.085
			(1.97) *	(2.38) **		(1.01)
Δ No. of partners, *t*-4…*t*-3			.002	-.003		.158
			(.06)	(.13)		(1.79) *
Δ Centrality, *t*-1…*t*		.262		.007	.031	.007
		(3.63) ***		(1.10)	(1.23)	(.22)
Δ Centrality, *t*-2…*t*-1		.561		.017	-.045	-.003
		(7.54) ***		(2.33) **	(1.83) *	(.10)
Δ Centrality, *t*-3…*t*-2		.464		.015	-.021	.034
		(6.36) ***		(2.10) *	(.93)	(1.07)
Δ Centrality, *t*-4…*t*-3		.428		-.010	-.040	.000
		(5.98) ***		(1.47) +	(1.89) *	(.00)
Mkt share of investments	.082	-.018	-.001	-.003	-.053	-.037
	(1.41)	(.33)	(.12)	(.44)	(2.59) **	(1.69) +
Capital under mgmt (log)	.000	.000	.000	.000	.000	.000
	(.91)	(.44)	(2.49) *	(2.81) **	(2.00) *	(1.01)
Firm age (log)	-.501	-.162	-.033	-.032	-.171	-.028
	(5.60) ***	(1.72) +	(2.94) **	(2.86) **	(6.31) ***	(.70)
Firm located in CA?	.092	.068	.002	.004	.025	-.086
	(.76)	(.57)	(.14)	(.29)	(.66)	(1.99) *
Firm located in MA?	.076	.014	-.003	-.003	.040	.017
	(.52)	(.10)	(.23)	(.27)	(.89)	(.32)
Early stage %	-.361	-.504	.048	.050	.229	.265
	(1.07)	(1.54)	(1.61)	(1.66) +	(2.17) *	(2.05) *
Later stage %	-.194	-.119	-.037	-.039	-.651	-.541
	(.52)	(.33)	(1.18)	(1.22)	(5.49) ***	(3.99) ***
(Industry controls not shown)						
Constant	1.400	1.033	.097	.100	.616	.489
	(4.56) ***	(3.50) ***	(2.71) **	(2.85) **	(5.96) ***	(3.13) **
p-value	0.000	0.000	0.000	0.000	0.000	0.000
Wald χ^2-statistic	584.1	716.7	189.5	212.4	160.8	280.2
N	1269	1269	842	842	1269	1269

The results of our analyses indicate that prior positions tend to determine venture capital firms' subsequent positions in the syndication network. Thus, our results provide support for Hypothesis 2b and the social structural view of the determinants of exchange in venture capital syndication networks. In addition, Hypothesis 1 on the positive relationship between centrality and subsequent performance is supported. The results also indicate that causality runs from centrality to performance, not vice versa. Prior

positions tend to determine the subsequent positions of venture capital firms. Position centrality, in turn, reinforces performance, but with a longer time lag.

The acquisition of general partners, on the other hand, appears to act as a vehicle to affect position. While position would otherwise seem to be a given, stable characteristic of a venture capital firm, changes in the number of general partners can disrupt the system. Firms that gain centrality also tend to gain general partners, and firms that gain general partners tend to gain centrality. There is a feedback relationship between the two variables. We argue that the feedback relationship may result from the introduction and removal of the personal collaboration networks of the general partners when they enter or leave a firm. While our data does not allow an explicit analysis of the partner-level networks, the significant macro-level relationship between changes in the stock of partners and firm position suggests that additions and reductions in the number of general partners have a direct impact on the network position of the firm.

To further ensure the robustness of the results, we ran the same analyses using equal-weighted IPO market shares instead of value-weighted ones, and ran the models on several different periods. Despite the modifications, the results were qualitatively the same as presented in this paper.

5 DISCUSSION AND CONCLUSIONS

This paper set out to examine how the network position and the performance of venture capital firms are related to each other, whether position and performance reinforce each other over time, and whether the social structure of the network or the observable quality of resources is the dominant determinant of collaborative exchange. A large data set composed of the investments by a set of U.S. venture capital firms over the period 1986 – 2000 was utilised in the analysis.

We formulated three hypotheses on the basis of the resource-based view and the social structural view. The resource-based view of the firm predicts that venture capital firms benefit from a central network position by enhancing their access to the resources of the syndicate partners. As a result, previous central positions should be associated with above-average current performance. Similarly, companies with an attractive resource base, or resources that are complementary to the resources of other network firms, should be attractive exchange partners. As track record acts as a signal of the quality of the firm's resources, above-average past performance should intensify resource exchange with the focal firm. As a result, the focal firm may be able to improve its position centrality.

On the other hand, the social structural view predicts that organisations can benefit from central network positions because a central position implies that the firm possesses informational advantages and high social status. Informational advantages arise because connectedness provides central firms with rich information on the quality of potential exchange partners. High status acts as a signal of quality and makes organisations

associated with the high-status actor desirable. Because of such effects, firms tend to prefer exchanges with central firms, which tend to sustain their past positions in the co-operative network. While the resource-based view stresses that the quality of the focal firm's resources determines the willingness of other firms to exchange with it, the social structural argument is that the prior position of the focal firm is the major determinant of tie formation. Thus, the past centrality of venture capital firms may determine their subsequent centrality. Our longitudinal data set allowed us to test not only the hypotheses but also causality in the hypothesised relationship between firm performance and position.

The results of this paper demonstrate that network positions contribute to performance, and that past positions constitute a dominant determinant of subsequent positions. Firstly, past position centrality in the syndication network is positively related to the subsequent performance of the firm. Past performance is also positively related to subsequent performance. Secondly, past position centrality is positively related to subsequent centrality, but past performance does not appear to be related to subsequent position centrality in the syndication network. Even though well-performing peripheral venture capital firms could signal that they possess high-quality resources, the centrality of these firms does not seem to improve as a result of past performance alone. According to our results, the performance and the position centrality of a venture capital firm are positively interrelated, but causality runs from centrality to performance – not vice versa. Our results also indicate that there exist a positive feedback loop among venture capitalists that gain on general partners or gain on centrality. Changes in the "stock" of general partners can disrupt existing network positions.

The results have several implications. On the theoretical side, this paper supports the social structural view of interorganisational co-operative networks, and implies that a firm's position in co-operative networks has an impact on its performance. Interestingly, we find that past centrality is a determinant of subsequent performance but that past performance is not a determinant of subsequent position centrality. This suggests that venture capital firms gain centrality by means other than signalling the quality of their resources. Our results indicate that one such mechanism is related to changes in the stock of general partners in the firm. Our initial suggestion is that the personal collaborative networks of individual general partners expand the existing network of the focal firm after the partners have joined the firm, thus improving the centrality of the firm. Similarly, we suggest that the network of the firm loses dyads when a partner leaves the firm, leading to a reduction in the centrality of the firm's position in the overall syndication network. While our data does not allow an explicit analysis of the personal networks of the general partners, the significant feedback relationship between changes in centrality and changes in the number of general partners suggests that general partners have a direct impact on the position of the firm.

On the practical side, the results of this paper provide some suggestions regarding successful strategies for venture capital firms. It is evident that syndication is a valuable vehicle for achieving a protected high-status position that tends to lead to above-average performance. The strong tendency of sustaining prior positions additionally implies that there may exist considerable barriers to success in the venture capital industry. It is difficult for a peripheral newcomer to gain the same number of positive effects from exchange relationships as central firms gain. Central positions are valuable and worth sustaining. Newcomers might find it rewarding to seek such positions by actively building exchange relationships through investment syndication, and by carefully building their stock of general partners to integrate their personal networks to a firm network.

This paper has left some interesting questions open. Firstly, we have only provided a starting point to examine which mechanisms can disrupt the existing network structure, or why the dyads are initially formed as they are. One potential direction for future research would be to examine the entry into and exit from the syndication network. As we initially outline, the formation and the sustainability of the dyads seem to be associated with the networks of the individual general partners rather than the venture capital firm as an organisation. As our results initially suggest, the introduction of new general partners and the exchange of general partners among the network firms may act as exogenous and endogenous shocks to the network structure, and seem to have an effect on the centrality of the firms. Further research could examine the networks of the individual general partners in more detail to better understand the effects of such shocks.

Secondly, further research could still extend the testing and elaboration of the resource-based and the social structural reasons for initiating syndicates and other collaborative exchange relationships. While it is probably true that firms prefer to continue to use their existing exchange relationships, and thus tend to protect existing positions, the stimulus for initiating the first exchanges is likely to be attractive resources. Exchange relationships are formed because firms want to exchange something. Knowledge about the extent of resource exchange in collaborative relationships, and especially venture capital syndicates, would shed light on the issue of initiating exchanges.

REFERENCES

Ahuja G. 2000a. The duality of collaboration: Inducements and opportunities in the formation of interfirm linkages. *Strategic Management Journal* 21: 317 – 343.

Ahuja G. 2000b. Collaboration Networks, Structural Holes, and Innovation: A Longitudinal Study. *Administrative Science Quarterly* 45(3): 425 – 455.

Akerlof, G. 1970. The Market for Lemons: Quality Uncertainty and the Market Mechanism. *Quarterly Journal of Economics* 84(3): 488 – 500.

Anand B, Piskorski MJ. 2001. *Money can't buy my love: Financial resources and network positions in the formation of venture capitalist syndicates*. Working paper, Harvard Business School.

Baker WE. 1984. The Social Structure of a National Securities Market. *American Journal of Sociology* 89: 775 – 811.

Barney J. 1991. Firm resources and sustained competitive advantage. *Journal of Management* 17: 99 – 120.

Baum JAC, Oliver C. 1991. Institutional linkages and organizational mortality. *Administrative Science Quarterly* 36(2): 255 – 291.

Baum JAC, Calabrese T, Silverman B. 2000. Don't go it alone: Alliance network composition and startups' performance in Canadian biotechnology. *Strategic Management Journal* special issue 21(3): 267 – 294.

Benjamin BA, Podolny JM. 1999. Status, Quality, and Social Order in the California Wine Industry. *Administrative Science Quarterly* 44: 563 – 589.

Bonacich P. 1987. Power and Centrality: A family of measures. *American Journal of Sociology* 92: 1170 – 1182.

Brander J, Amit R, Antweiler W. 1999. *Venture Capital Syndication: Improved Venture Selection versus the Value-Added Hypothesis.* Working paper, University of British Columbia.

Bygrave WD. 1987. Syndicated Investments by Venture Capital Firms: A Networking Perspective. *Journal of Business Venturing* 2(2): 139 – 154.

Bygrave WD. 1988. The Structure of the Investment Networks of Venture Capital Firms. *Journal of Business Venturing* 3: 137 – 158.

Bygrave WD, Timmons JA. 1992. *Venture Capital at the Crossroads*. Harvard Business School Press: Boston, MA.

Carter RB, Manaster S. 1990. Initial Public Offerings and Underwriter Reputation. *Journal of Finance* 45(4): 1045 – 1067.

Dierickx I, Cool K. 1989. Asset stock accumulation and sustainability of competitive advantage. *Management Science* 35: 1504 – 1511.

Eisenhardt KM, Schoonhoven K. 1990. Organizational Growth: Linking Founding Team, Strategy, Environment, and Growth among U.S. Semiconductor Ventures, 1978 – 1988. *Administrative Science Quarterly* 35: 504 – 529.

Gompers PA. 1995. Optimal Investment, Monitoring, and the Staging of Venture Capital. *Journal of Finance* 50(5): 1461 – 1489.

Gompers PA. 1996. Grandstanding in the Venture Capital Industry. *Journal of Financial Economics* 42(1): 133 – 156.

Gompers PA, Lerner J. 1998. *The Determinants of Corporate Venture Capital Successes: Organizational Structure, Incentives, and Complementarities*. NBER Working Paper No. W6725.

Gompers PA, Lerner J. 1999a. An analysis of compensation in the U.S. venture capital partnership. *Journal of Financial Economics* 51(January): 3 – 44.

Gompers PA, Lerner J. 1999b. *The Venture Capital Cycle.* The MIT Press: Cambridge, MA.

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

Granger CWJ. 1969. Investigating Causal Relations by Econometric Methods and Cross-Spectral Methods. *Econometrica* 34: 424 – 438.

Granovetter M. 1985. Economic action and social structure: A theory of embeddedness. *American Journal of Sociology* 91: 481 – 510.

Gulati R. 1995. Social structure and alliance formation patterns: A longitudinal analysis. *Administrative Science Quarterly* 40(4): 619 – 652.

Gulati R. 1999. Network location and learning: The influence of network resources and firm capabilities on alliance formation. *Strategic Management Journal* 20: 397 – 420.

Hagedoorn J, Schakenraad J. 1994. The effect of strategic technology alliances on company performance. *Strategic Management Journal* 15(4): 291 – 309.

Hellmann T, Puri M. 2002. Venture Capital and the Professionalization of Start-up Firms: Empirical Evidence. *Journal of Finance* 57(1): 169 – 197.

Hsiao C. 1986. *Analysis of panel data*. Cambridge University Press: Cambridge.

Kogut B. 1988. A study of the life cycle of joint ventures. *Management International Review* special issue 28: 39 – 52.

Lerner J. 1994. The Syndication of Venture Capital Investments. *Financial Management* 23(3): 16 – 27.

Lockett A, Wright M. 2001. The syndication of venture capital investments. *Omega* 29: 375 – 390.

MacMillan IC, Kulow DM, Khoylian R. 1988. Venture Capitalists' Involvement in Their Investments: Extent and Performance. *Journal of Business Venturing* 4(1): 27 – 47.

Megginson WL, Weiss KA. 1991. Venture Capitalist Certification in Initial Public Offerings. *Journal of Finance* 46(3): 879 – 903.

Merton RK. 1968. The Matthew effect in science. *Science* 159: 56 – 63.

Miner AS, Amburgey TL, Stearns TM. 1990. Interorganizational linkages and population dynamics: Buffering and transformational shields. *Administrative Science Quarterly* 35(4): 689 – 713.

Mitchell W, Singh K. 1996. Survival of businesses using collaborative relationships to commercialize complex goods. *Strategic Management Journal* 17(3): 169 – 195.

Nohria N, Garcia-Pont C. 1991. Global Strategic Linkages and Industry Structure. *Strategic Management Journal* summer special issue 12: 105 – 124.

Penrose E. 1959. *The Theory of the Growth of the Firm*. Oxford University Press: New York, NY.

Pfeffer J, Salancick GR. 1978. *The External Control of Organizations: A Resource Dependence Perspective.* Harper & Row: New York, NY.

Podolny JM. 1993. A Status-Based Model of Market Competition. *American Journal of Sociology* 98: 829 – 872.

Podolny JM. 1994. Market Uncertainty and the Social Character of Economic Exchange. *Administrative Science Quarterly* 39: 458 – 483.

Podolny JM. 2001. Networks as Pipes and Prisms of the Market. *American Journal of Sociology* 107(1): 33 – 60.

Powell WW, Kogut KW, Smith-Doerr L. 1996. Interorganizational collaboration and the locus of innovation: Networks of learning in biotechnology. *Administrative Science Quarterly* 41(1): 116 – 145.

Sahlman WA. 1990. The Structure and Governance of Venture-Capital Organizations. *Journal of Financial Economics* 27: 473 – 521.

Sapienza HJ. 1992. When Do Venture Capitalists Add Value? *Journal of Business Venturing* 7(1): 9 – 27.

Sorenson O, Stuart T. 2001. Syndication Networks and the Spatial Distribution of Venture Capital Investments. *American Journal of Sociology* 106(6): 1546 – 1588.

Spence AM. 1974. *Market Signaling: Informational Transfer in Hiring and Related Screening Processes*. Harvard University Press: Cambridge, MA.

Stuart TE. 1998. Network positions and propensities to collaborate: An investigation of strategic alliance formation in a high-technology industry. *Administrative Science Quarterly* 43(3): 668 – 698.

Stuart TE, Hoang H, Hybels R. 1999. Interorganizational Endorsements and the Performance of Entrepreneurial Ventures. *Administrative Science Quarterly* 44(2): 315 – 349.

Wernerfelt B. 1984. A resource-based view of the firm. *Strategic Management Journal* 5(2): 171 – 180.

White HC. 1981. Where do markets come from? *American Journal of Sociology* 87: 517 – 547.

Wilson R. 1968. The theory of syndicates. *Econometrica* 36(1): 119 – 132.