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Determinants of the returns to venture capital investments

Abstract

Motivated by the Berk, Green and Naik (1999) model of the relations between firms’ optimal investment choices, growth options and expected returns, this study examines the relations between firm size, book-to-market ratios and the returns to venture capital investments. I find that the excess returns earned by U.S. biotech firms between their venture capital financing rounds are negatively related to firm size and positively related to firm book-to-market ratios. However, excess returns are also explained by many other market-wide, investor-specific, and firm-specific variables. I hypothesize that this diversity in pricing arises because venture capital markets are more imperfect and therefore provide less opportunity to diversify away non-systematic risks than public markets. Consistent with this view, more factors are priced in venture capital returns than in public equity returns, and the beta on the public market return is much larger in the public equity market than it is in the venture capital market. The latter result parallels the increase in the beta on the world stock return that occurs when previously segmented emerging markets liberalize and integrate into global capital markets.

Key words: Biotechnology; growth options; investments; market liquidity; pricing factors; risk; return; venture capital.

JEL classifications: G12, L65, M13, M41.
1. Introduction and summary

Much is known about the determinants of the returns to public equity. Over the past thirty years, factors such as beta, size, book-to-market, momentum, liquidity, cash flow volatility, and the level, quality, persistence and predictability of earnings have been found to reliably explain cross-sectional and intertemporal variation in the expected and/or realized returns to publicly traded common stocks (e.g., Fama and MacBeth, 1973; Brav, Lehavy and Michaely, 2003; Banz, 1981; Statman, 1980; Fama and French, 1992, 1996; Jegadeesh and Titman, 1993; Amihud, 2002; Francis, LaFond, Olsson and Schipper, 2003).

In contrast, little is known about the determinants of the returns to private equity, beyond the observation that venture capital returns are positively related to public equity returns (Gompers and Lerner, 1998; Cochrane, 2003). Venture capital is the subsector of private equity having to do with equity investments in young, typically high technology firms. The goal of this paper is to begin to close this gap by addressing two research questions. First, how are firm size and firm book-to-market ratios priced in the cross-section of venture capital returns, and why? Second, what effects do the distinctive economic features of the venture capital market have on returns, and why?

The first research question is motivated by the fact that venture capital investors specialize in funding young, rapidly evolving and highly risky firms that have large growth options (Gompers and Lerner, 2000a). This makes such companies an ideal sample through which to evaluate the relations between expected returns, investments, growth options, and assets in place. Berk, Green and Naik (1999) develop the implications for expected returns when firm risk is endogenously determined by the firm’s dynamically exploitation of its investment opportunities. In their model, firm size is negatively related to expected returns because it is a proxy for the state variable that describes the relative importance of the firm’s existing assets versus growth options. The book-to-market ratio is positively related to expected returns because it serves as a state variable summarizing the firm’s risk relative to the scale of its asset base. Prompted by these insights, I hypothesize that firm size (book-to-market ratio) will be negatively (positively) associated with the returns to venture capital investments.

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1 Beyond venture capital, private equity includes leveraged buy-outs, late-stage mezzanine investments, and PIPES (private investments in public equities). Such private equity investments often include more debt than equity. Venture capital falls at the earlier firm-life stage in the private equity spectrum.
The second research question I address is provoked by the fact that although firms financed by venture capital and public equity undertake the same types of financing, investing, and operating activities, the venture capital market differs from the public equity market in significant structural ways (Gompers and Lerner, 2000a). In particular, the venture capital market is highly illiquid and imperfect. This makes it either infeasible or economically suboptimal for venture capital investors to fully diversify away idiosyncratic risks. These and other differences lead me to propose three additional hypotheses.

First, I propose that more factors will be priced in the venture capital market than just firm size and book-to-market ratios. Extant theoretical and empirical work suggests that the presence of market imperfections leads to the pricing of idiosyncratic risk (e.g., Levy, 1978; Malkiel and Xu, 2002; Hou and Moskowitz, 2003). Second, I hypothesize that more factors will be priced in the venture capital market than in the public equity market because the former is more imperfect than is the latter. Third, I hypothesize that the loading on the public equity market return will be higher in the public equity market than it is in the venture capital market because the incompleteness of the venture capital market leads to the spreading of firms’ total return variance over more pricing factors, with the result that the magnitude of the loading on each factor is smaller.

The dataset I use to test these hypotheses is derived from that employed by Hand (2003a). It consists of a detailed set of panel data for 193 U.S. biotechnology companies over the period 1992–2003. Young biotech firms are typically financed in well-defined stages by professional venture capital and have large fractions of their equity value in the form of growth options. Biotech firms also go public quite quickly, so financial statement data spanning a firm’s entire life are often available in its IPO filing documents. This is critical for assessing the relation between returns and firms’ book-to-market ratios, because book or asset values can only be obtained from firms’ financial statements at an IPO filing. Private firms are not required to disclose financial statement data and rarely do so voluntarily, especially when they are young.

The database matches the pre-money venture capital valuations of a large set of biotech firms with up to five years of annual financial statement data from the IPO filings of the subset that filed to go public. Pre-money valuations are firm equity values before the infusion of capital in a funding round. This yielded 481 venture capital valuation points (spanning Series A to Series H rounds) that were accompanied by the preceding fiscal year’s financial statements.
Appropriately first-differencing the pre-money valuations produced a set of 288 “round-to-round” venture capital returns for 157 firms. Public market returns were collected for those sample firms that successfully went public. The valuation points were three months after each of the first three fiscal year-ends following the IPO. This yielded 289 annual public equity market returns spanning 154 firms.

The venture capital returns regression model is derived from the log-linear model of a firm’s pre-money equity valuation developed by Hand (2003a), which in turn is motivated by the log-linear specifications employed by Lerner (1994a), Gompers and Lerner (1999) and Seppä (2003). Firm-specific round-by-round excess returns are posited to be a log-linear function of a diverse set of risk factors, financial statement data, and non-financial statement information. Excess returns are raw returns less the riskfree rate over the return horizon. The risk factors included are firm size, book-to-market, age, the return on publicly traded biotech stocks, and the return on all venture capital financed pre-IPO biotech firms. Financial statement data consist of the logarithmic growth rates in firms’ cash, noncash assets, R&D expenditures, and stock option dilution. Non-financial statement information includes the logarithmic growth rates in the number of firms’ patent filings and the scope/breadth of patents filed, the number of firms’ strategic alliances, the number of shares outstanding, and the dilution created at financing dates, plus indicators for the type of investor leading the current and prior financing rounds, and whether the same investor led both rounds. The last four variables are unavailable for post-IPO observations.

The results of the returns regressions are broadly consistent with each of the paper’s four hypotheses. First, excess returns earned between biotech firms’ venture capital financings are negatively related to firm size and positively related to firm book-to-market ratios. I view this as consistent with the Berk, Green and Naik (1999) theory that firm size and book-to-market ratios are related to expected returns because they are proxies for state variables that describe how the systematic component of firm risk changes through time as firms optimally exploit their investment opportunities. I do not interpret the pricing of firm size and book-to-market ratios as being consistent with the Fama and French (1993) view that firm size and book-to-market are proxies for distress risk, because sample firms’ book-to-market ratios are very low, not high, and the selection bias imposed by requiring that sample firms file to go public suggests that sample firms are successful, not distressed. Nor do I interpret the pricing of firm size and book-to-
market ratios as being consistent with the Lakonishok, Shleifer and Vishny (1994) view that high book-to-market (“value”) stocks earn high returns because some price-moving investors incorrectly extrapolate their past poor earnings growth rates. Venture capital investors are highly sophisticated, and young biotech firms have little history from which to extrapolate. I also do not interpret the pricing of firm size and book-to-market ratios in venture capital investments as a foregone replication of prior findings from public equity studies, because this is the first research to examine the pricing of firm size and book-to-market ratios outside of public equity markets. As such, my results are free from data snooping criticisms of the kind raised by MacKinlay (1995). In addition, the number of observations is so small relative to public market studies that the significance of the estimated coefficients on firm size and book-to-market ratios is most reasonably attributed to the statistical power created by my quasi-experimental setting—i.e., one of young, rapidly evolving firms that have large growth options.

The results from the venture capital return regressions are also consistent with the hypothesis that venture capital returns are determined by a broader set of factors than firm size and book-to-market ratios alone. In all, I find that venture capital returns are reliably explained by twelve variables. Of these, four are risk-related factors, three are based on financial statement data, and five are items of non-financial statement information. Beyond firm size and book-to-market ratios, venture capital returns are negatively related to firm age and positively related to the return on publicly traded biotech stocks. Returns are also positively related to the rate of growth in firms’ assets, noncash assets, and R&D expenditures. In terms of non-financial statement data, venture capital returns are negatively related to the growth in the dilution created at financing dates, are higher (lower) if the lead investor in the current (prior) financing round is a corporation rather than a venture fund, are lower if the lead investor in the current round is the same as that in the prior round, and are negatively related to the growth in shares outstanding.

Consistent with the hypothesis that more factors will be priced in venture capital returns than in public equity returns, I find that many of the factors priced in venture capital returns are not priced in public market returns. Of the nine factors priced in venture capital returns for which data are available in the public market (i.e., excluding the growth in dilution and indicators related to the identity of the lead investor), only three are priced during the initial years that sample firms trade publicly. This suggests that the venture capital market is more incomplete, illiquidity and imperfect than the public equity market.
The last regression finding of note is that the coefficient on the return to publicly traded biotech stocks (“beta”) is 0.28 in the venture capital market and 1.38 in the public equity market. This result is consistent with the fourth hypothesis of the paper, that a lower beta will be observed in the venture capital market because severe frictions there lead to incomplete diversification and a larger number of lower priced factors. The finding for beta somewhat parallels certain results in international finance, where the beta on the world equity return has been shown to increase when previously segmented emerging markets liberalize and integrate into world capital markets (Bekaert and Harvey, 1995, 2000).

In total, this paper contributes to several areas of research. By showing in a distinctive, new and unsnooped setting that firm size and firm book-to-market ratios are related to returns, it adds to what is known about the pricing of size and book-to-market ratios, and why such pricing occurs. In particular, the strength of the pricing of firm size and book-to-market ratios supports the Berk, Green and Naik (1999) model of the dynamic relations between returns and firms’ investment opportunities. The paper also contributes to the growing empirical literature that documents the impacts of market frictions on the cross-sectional pricing of idiosyncratic risks, and to the literature in entrepreneurial finance that seeks to understand the drivers of equity value in private equity markets. Further, it provides new evidence concerning the effects of market structure on equity returns, echoing results found in the international finance literature on emerging capital markets. Finally, the paper contributes to the value relevance literature in accounting by showing that financial statement data are associated with returns in a setting in which financial statements might be thought to be value irrelevant.

The remainder of the paper proceeds as follows. Section 2 describes the institutional background of the private equity and venture capital markets and summarizes prior research into venture capital and biotechnology. Section 3 derives in detail the four hypotheses that the study proposes and seeks to test. Section 4 develops the models of firms’ pre-money equity valuations and round-to-round equity returns. Section 5 outlines the data set used in this study and reports descriptive statistics. Section 6 reports and interprets the results of regressions that estimate the pre-money valuation and round-to-round return models in venture capital and public equity markets. Section 7 concludes.
2. Private equity and venture capital

2.1 Institutional background

The private equity market is made up of four submarkets: organized, angel, informal, and Rule 144A (Fenn, Liang and Prowse, 1995). This paper focuses on the venture capital sector within organized private equity. As a whole, organized private equity is defined as unregistered investments in the equity of private companies, made either directly by professional investors such as corporations, pension funds, and endowments or indirectly by these investors through intermediaries, particularly venture capital partnerships. Funds invested in organized U.S. private equity have grown substantially over the past two decades, rising from $5 billion in 1980 to almost $300 billion in early 2001 (Lerner, 2001). Private equity funds invest in a wide variety of vehicles, including young companies, leveraged buyouts, consolidations, mezzanine financing, and distressed debt. Of private equity funds, venture capital partnerships are the most common.

Private equity markets differ from public equity markets in substantive ways (Wright and Robbie, 1998; Gompers and Lerner, 2000a). Private equity markets are less complete, less liquid, and offer less diversifiability. There is no short selling in private equity markets. Public equity markets are highly regulated by the S.E.C. and stock exchanges, while private equity markets are not. Private equity firm valuations are set through face-to-face negotiations between management and a small number of wealthy, professional and risk-tolerant investors. Valuations in a public equity market are set anonymously without direct contact with management via the interactions of large numbers of investors, many of whom are risk-averse and do not have significant wealth or professional investing experience. Trading is cheap and all but continuous in public equity markets, but expensive and rare in private equity markets. Firms in the mostly unregulated pre-IPO stage of life are younger, more intangible-intensive, have larger investment

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2 This section draws heavily on section 2 of Hand (2003a).
3 This interpretation of private equity is much tighter than one defines all non-publicly traded equity as private equity (e.g., Moskowitz and Vissing-Jørgensen, 2002). For example, Quigley and Woodward (2002) note that there are more than 20 million companies in the U.S. that file income tax returns.
4 Angel private equity consists of investments made by wealthy individuals, typically arranged by matchmakers such as lawyers and accountants (Wong, 2002). Informal private equity is similar to angel capital except that firms sell unregistered equity securities to both institutional investors and wealthy individuals across a larger number of such investors. Rule 144A private equity is private equity offerings underwritten under the SEC’s Rule 144A, which establishes the rules and conditions under which private securities are permitted to be traded among certain classes of institutional investors (Fenn, Liang and Prowse, 1995).
opportunity sets relative to assets in place, face greater uncertainty, and have more concentrated ownership than do publicly traded firms. Private equity investors can also extract more of management’s private information because of the board positions they hold and their frequent interactions with and monitoring of management. Public equity investors typically engage in indirect monitoring, rely primarily on public data and face significant information asymmetries.

2.2 Venture capital

Venture capital is independently managed, dedicated capital invested in young, usually startup or early-stage technology businesses that are highly risky but also have very strong future growth and profit potential. Venture capital funds are typically structured as partnerships of venture capitalists that raise money in staged amounts from companies, institutions, and wealthy private investors. A fund usually has a ten-year life and invests in a portfolio of private companies, often restricted to one or two sectors such as biotechnology or software. Although venture capitalists put up only about 1% of the limited partnership’s capital, they manage the fund through their role as general partners. In exchange for finding, screening, and deciding upon the companies to invest in, venture capitalists are paid an annual management fee that is usually between 1.5% and 3% of the fund’s committed capital or net asset value, and they receive about 20% of the profits made by the fund’s investments.

The typical investment made by a venture capitalist is in illiquid preferred stock that is only convertible into liquid common stock or cash at one of two major exit points—an IPO or the sale of the company to another entity. This usually occurs within a targeted window of a certain number of years. Although venture capitalists provide a firm a measure of long-term financing by investing in several financing rounds, they also supply business expertise and connections. The venture capitalist usually serves on the firm’s board of directors; provides financial sophistication, operating services, and a network of business contacts; helps recruit key personnel; and imparts financial and strategic discipline to management.

2.3 Venture capital research

Research in entrepreneurial finance has blossomed over the past decade as researchers have exploited the fact that private equity investors such as venture capitalists face many of the same problems as do public investors but to a more severe degree. An excellent summary is
provided by Gompers and Lerner (2000a), spanning topics such as the compensation of venture capitalists (Gompers and Lerner, 1999); the optimal investment, monitoring, and staging of venture capital (Gompers, 1995); the decision to go public (Lerner, 1994b); and the long-run performance of venture-backed IPOs (Brav and Gompers, 1997). Most recent work includes that of Kaplan and Stromberg (2003a, b) who empirically relate the characteristics of venture capital contracts to theories of financial contracting, and Seppä (2003), who examines the relations between investment syndication and the efficiency of venture capital firms, and the role of network positions in determining the performance of venture capital firms.

Research specifically concerning the returns to private equity has focused on describing the basic risk and return profiles of investments in private equity partnerships and private equity investments in companies. For example, Kaplan and Schoar (2003) conclude that average fund returns net of fees approximate those of the S&P 500, persist strongly across funds raised by individual partnerships, and improve with partnership experience. Ljungqvist and Richardson (2003) report that the risk-adjusted excess value of the typical private equity fund is on the order of 24% relative to the present value of invested capital, probably because of the highly illiquid nature of the fund. Using data from VentureOne, Cochrane (2003) measures the return, standard deviation, alpha and beta of individual venture capital investments after correcting for the selection bias created by the greater availability of valuations for successful firms. For a large set of financing rounds from VentureXpert, Das, Jagannathan and Sarin (2002) finds that the probability of exit, the valuation multiple, and the expected investment gains depend on industry, firm stage-of-life, the financing amount, and prevailing market sentiment.

2.4 Biotechnology and business research into biotechnology companies

Biotechnology is the application of technology to the life sciences, wherein living cells or their processes are used to solve problems and to perform specific industrial or manufacturing processes. Biotech applications include the production of drugs, synthetic hormones and bulk foodstuffs; the bioconversion of organic waste; and the use of genetically altered bacteria. Biotech firms are highly dependent on the intellectual property (ideas, discoveries, patents) generated through their large R&D expenditures, and as such are among the most intangible-intensive of businesses. The value chain of the typical biotech firm stretches some 10–15 years from founding through patenting to successful FDA approval and product sales. Biotechnology
is therefore a very risky but potentially very lucrative equity investment.

<< Insert Figure 1 here >>

The prototypical young biotech firm is in an intense R&D race against competitors to discover and patent a new drug. It therefore has large capital needs over a long period of time. In the early stages of life, the firm’s capital needs are met by venture capital and strategic equity investments from pharmaceutical companies. However, capital needs eventually become so large that they can only be satisfied via an IPO or a buyout by a large pharmaceutical company. Successful biotech firms therefore tend to go public rapidly, and it is not uncommon for a biotech firm’s S-1 filing with the S.E.C. to contain financial statements that span its entire life.

Economic research into biotechnology has spanned three areas: intellectual capital (Zucker and Darby, 1996; Zucker, Darby and Brewer, 1998), strategic alliances (Robinson and Stuart, 2002), and valuation (Stuart, Hoang and Hybels, 1999; Nicholson, Danzon and McCullough, 2003; Darby, Liu and Zucker, 1999). In accounting, Joos (2002) finds that the level and rate of growth in R&D expense; R&D success; and competitive structure explain cross-sectional variation in market-to-book ratios for pharmaceutical drug manufacturers. Ely, Simko and Thomas (2003) conclude that the average FDA stage of a firm’s portfolio of drugs conditions the value relevance of the firm’s R&D expenditures. Guo, Lev and Zhou (2003) find that biotech firms’ disclosures affect their bid-ask spreads and stock return volatility. Hand (2003b) reports that the mapping of publicly traded biotech firms’ R&D expenditures into equity market value is a function of the location of R&D in the biotech value chain of discovery, development and commercialization, as well as the growth rate in R&D spending.

3. Hypothesis development

3.1 The pricing of firm size and book-to-market ratios in venture capital returns

In a series of major papers, Fama and French (1992, 1993, 1996) conclude that firm size and book-to-market ratios capture cross-sectional variation in average returns missed by univariate CAPM market betas and also explain the strong patterns in returns observed when portfolios are formed on earnings-to-price ratios, cashflow-to-price ratios, sales growth, and long-term past returns. Financial economists have put forward four explanations for these findings. Three predict that firm size and book-to-market ratios will not be priced in the cross-
section of venture capital returns, while the fourth predicts that firm size and book-to-market ratios will be priced.

3.1.1 Standard explanations for the pricing of firm size and book-to-market ratios in the cross-section of publicly traded stock returns

The default explanation, favored by Fama and French, is that firm size and book-to-market footprints in returns are due to rational multifactor ICAPM or APT pricing, such that firm size and book-to-market ratios are proxies for state variables that hedge non-CAPM beta risk. In particular, Fama and French (1993) interpret the size and book-to-market variables as proxies for state variable risk related to relative distress, with small-sized and high book-to-market firms having higher distress risk than large-sized or low book-to-market firms.

In sharp contrast, Lakonishok, Shleifer and Vishny (1994) propose that the high discount rates earned by small-sized and high book-to-market firms reflect irrational extrapolations by investors of firms’ earnings growth rates. Specifically, they argue that investors fail to understand that abnormal earnings growth rates dissipate rapidly. Investors are therefore improperly optimistic about the future earnings growth rates of firms with high recent growth in earnings, and improperly pessimistic about the future earnings growth rates of firms with low or negative recent growth in earnings. Acting on their misperceptions, investors erroneously push up the prices of “growth” firms (that have low book-to-market ratios), and push down the prices of “value” firms (those with high book-to-market ratios). The gradual reversion of prices toward fundamental values then creates a positive correlation between returns and book-to-market ratios.

The third category of explanations consists of survivorship bias, data snooping or economic irrelevance. Kothari, Shanken and Sloan (1995) suggest that survivorship bias occurs because Compustat is more likely to include distressed firms that survive and omit distressed firms that fail. MacKinlay (1995) argues that data snooping arises because repeated analysis of CRSP data is almost sure to yield findings that appear anomalous, but in reality merely reflect in-sample data mining and misplaced reliance on classical statistics. Knez and Ready (1997) find using robust regression that the risk premium on firm size completely disappears when the most extreme 1% of observations are trimmed, while Loughran (1997) reports that the month of January drives the book-to-market effect and low returns on Amex and Nasdaq growth stocks drive the firm size effect, limiting their relevance to money managers.
I argue that the explanations outlined above predict that firm size and book-to-market ratios will not be priced in the cross-section of venture capital returns. Consider distress risk. Since most of their value resides in future investment options rather than assets in place, venture-backed firms have very low book-to-market ratios. Therefore, as measured by book-to-market ratios, venture-backed firms are rarely distressed. Moreover, while venture-backed firms are often small, those in my sample are among the most successful because they filed to go public. This performance-based selection bias works against using firm size as an indicator of distress.

Lakonishok, Shleifer and Vishny’s argument that the firm size and book-to-market effects are caused by investors’ irrational perceptions of earnings growth seems unlikely to hold, because venture capitalists are highly sophisticated. The limited partners who supply 99% of a venture fund’s capital have strong incentives to hire the most experienced and financially astute general partners to seek out the best investments (Gompers and Lerner, 2000a), and deep pockets from which to do so. Even if the marginal general partner were less than fully rational, young venture-backed companies have, almost by definition, little earnings history from which to extrapolate and such earnings history as exists is uniformly one of reported losses.5

Finally, a survivorship bias of the kind proposed by Kothari, Shanken and Sloan obtains only if the returns of distressed (viz., high book-to-market) firms are more likely than not to be recorded if the firm recovers from the distress. As already noted, my sample has no distressed firms as measured by book-to-market ratios. Additionally, data snooping biases will not affect the validity of inferences derived from statistical analysis of venture capital returns, because no work has yet examined the pricing of firm size and book-to-market ratios in such returns.

3.1.2 A growth options explanation for the pricing of firm size and book-to-market ratios in the cross-section of returns to publicly traded stocks

The most recent explanation of the pricing of firm size and market-to-book ratios in returns is a model developed by Berk, Green and Naik (1999). Berk, Green and Naik derive the implications for expected returns when firm risk is endogenously determined by the firm’s dynamic exploitation of its investment opportunities. The central feature of their model is that firms that perform well tend to be those that have discovered particularly valuable investment

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5 The dominance of reported losses among venture-backed firms occurs because young high-technology companies are typically in fierce innovation races with competitors. These races require large R&D expenditures and yield reported losses because FASB rules mandate that internally developed R&D must be expensed immediately.
opportunities. As they optimally exploit these opportunities, firms’ systematic risk changes as does their mix of assets in place versus investment options. By focusing on corporate investment decisions and distinguishing assets in place from growth options, Berk, Green and Naik enhance the dynamics of classic asset pricing theories such as Merton (1973).

The Berk, Green and Naik model derives a negative relation between firm size and expected returns because firm size is a proxy for the state variable that describes the relative importance of the firm’s existing assets versus growth options. The book-to-market ratio is positively related to expected returns because it serves as a state variable summarizing the firm’s risk relative to the scale of its asset base. It should be noted that the Berk, Green and Naik model differs from the traditional view that a firm’s book-to-market ratio captures its growth potential. Somewhat counterintuitively, they show that when a firm has no growth options, its expected return depends only on its book-to-market ratio.

Unlike other explanations, the Berk, Green and Naik model strongly predicts that firm size and market-to-book ratios will be priced in the cross-section of venture capital returns. This is because venture capital investors specialize in financing young, rapidly evolving, and highly risky firms that have large growth options. These are exactly the kinds of firms whose returns their model predicts will be most influenced by dynamic exploitation of the investment opportunities. Therefore, motivated by the Berk, Green and Naik model rather than conventional explanations, I propose the following hypothesis:

**H1:** Venture capital returns on investments in pre-IPO firms will be negatively related to firms’ equity values and positively related to firms’ book-to-equity value ratios.

3.2 The effects of the venture capital market’s distinctive features on venture capital returns

As described in sections 2.2 and 2.3, while venture-backed and publicly traded firms engage in similar kinds of financing, investing, and operating activities, the venture capital and public equity markets are structurally quite different. These differences lead me to propose the following hypotheses:

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6 The Berk, Green and Naik model also manifests return momentum at longer horizons and contrarian returns at short horizons. Positive correlations between current and lagged expected returns arise because the composition and systematic risk of a firm’s assets are persistent. Negative correlations between current expected returns and lagged realized returns occur because shocks to the composition of a firm’s assets are negatively related to changes in systematic risk. I do not test these predictions because my database contains relatively few lagged returns.
H2: More factors will be priced in venture capital returns than just firm size and book-to-market ratios.

H3: More factors will be priced in venture capital returns than in public equity returns.

H4: The magnitude of the loading on the market return will be lower in the venture capital market than in the public equity market.

My reasoning for proposing that more factors will be priced in venture capital returns is not that venture-backed firms are exposed to different types of fundamental business risks than are publicly traded firms. Rather, H2 and H3 stem from the observation that the venture capital market is substantially imperfect and is more imperfect than the public market. For example, short selling does not exist in the venture capital market. Venture capital investments are fairly indivisible and highly illiquid. The demand for venture capital funding is not perfectly elastic (Gompers and Lerner, 2000a). High levels of information asymmetry lead to infrequent trading, and the trading that does occur is almost entirely in the form of long investments in new equity, not secondary transactions. Equity prices of individual venture-backed firms are difficult and costly for non-participating investors to observe, and until very recently no comprehensive and unbiased valuation indices existed for the U.S. venture capital market.7

These imperfections place significant intra- and inter-market constraints on venture capital investors' ability to fully diversify. I therefore propose that it will be economically suboptimal to fully diversify away the idiosyncratic risks associated with venture capital investments. Therefore more idiosyncratic risks will be priced in venture capital returns than only firm size and book-to-market ratios, and more idiosyncratic risks will be priced in venture capital returns than are priced in public equity returns. While my argument is an intuitive one, it conforms to a stream of work that has modeled the effects of market frictions and incompleteness on diversification and idiosyncratic risk, either when exogenously imposed (Mayers, 1976; Levy, 1978) or when endogenously determined (Merton, 1987; Malkiel and Xu, 2002). Such models yield pricing equations that relate returns to their beta with the public equity market and their beta(s) with respect to idiosyncratic risk(s).

The reasoning behind hypothesis H4 is related to that for H2 and H3. I propose that as a firm moves from the venture capital arena into the public equity market, [1] the variation in its

7 Not everyone views features such as illiquidity as a symptom or reflection of market imperfections. For example, Lerner and Schoar (2003) model illiquidity as a choice variable in the fund’s general partners’ optimization problem.
returns explained by nonsystematic risk factors will decline while the variation in its returns explained by systematic risk factors will increase, and [2] the mechanism involved will be an increase in the magnitude of the loading on systematic risk factors. While intuitively appealing, this is not an impregnable argument. For example, it could be that moving into the public equity market lowers a firm’s return variance more than it lowers its error variance. However, H4 parallels what happens to the beta on the world return when previously segmented emerging markets liberalize and integrate into world capital markets. I argue that the parallel is appropriate because the transition from a private to a public equity market is economically analogous to the liberalization and integration of an emerging market into the world capital market (Harvey, 1995). In both a public equity market and the world capital market, portfolios can be better diversified, the costs of trading and selling short decline, markets become more liquid, and postintegration returns decline from their pre-integration levels (following a one-time increase at the integration date itself).

4. Modeling the returns to venture capital investments

4.1 A model of pre-money equity value

My model of the returns to venture capital investments is derived from the log-linear specification of the level of a firm’s pre-money value proposed by, and estimated in, Hand (2003a). Hand proposes that

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\text{LPREMV}_{ik} = \alpha + \sum_{f=1}^{F} \theta_f \text{LFS}_{fik} + \sum_{g=1}^{G} \gamma_g \text{LNFS}_{gik} + \epsilon_{ik},
\]

where \( \text{LPREMV}_{ik} \) is the log of firm \( i \)'s pre-money equity valuation at venture capital financing round \( k \), and \( \text{LFS} \) and \( \text{LNFS} \) are sets of log-transformed financial statement and non-financial statement information, respectively. Dollar variables \( Z \) are log-transformed according to \( \log_e[Z+1] \) where \( Z \geq 0 \) is in $000s, and nondollar variables \( Y \) are converted using \( \log_e[Y+1] \).

Also known as hedonic modeling, log-linear valuation has been used in several major studies in entrepreneurial finance, most notably Lerner (1994a), Gompers and Lerner (1999, 2000a, 2000b), and Seppä (2003). The log-linear specification has strengths and limitations as compared to alternatives such as Ohlson (1995). The main limitation is that the Ohlson model is both theoretically well-grounded and intuitively appealing, following as it does from a synthesis
of the dividend discount model with clean surplus accounting and autoregressive abnormal earnings. A log-linear valuation model is harder (although not impossible) to derive and, given its multiplicative Cobb-Douglas form, less intuitive.\textsuperscript{8}

Offsetting this limitation are several strengths. A log-linear specification flexibly accommodates nonlinearities in the relations between equity values and drivers. For example, the Ohlson (1995) model assumes that accounting is unbiased. This is not the case for biotech firms, given their huge spending on R&D. Also, while the Ohlson model does not per se rule out positive future NPV opportunities (Ohlson, 2003), neither does it unambiguously structure firms’ investment opportunity sets. Since young, start-up biotech companies are highly intangible intensive with large investment opportunities, and firms’ investment opportunity sets are by definition real options (Myers, 1977), relations between equity values and value drivers are quite likely to be nonlinear, and young biotech firms’ returns are likely to be highly skewed.

The second appealing feature of a log-linear model is econometric robustness. The log transformation substantially dampens the influence of anomalous observations or outliers, and typically yields a greater degree of homoscedasticity in regression residuals. This is likely a material benefit for the biotech firms used in this study, because biotech firms’ equity market values, total assets, R&D, revenues, etc. are highly skewed. Lastly, taking appropriate first differences of a log-linear valuation model neatly yields a log-linear model of returns.

Equation (1) employs disaggregated balance sheet and income statement data instead of simply book equity and net income, because Zhang (2001) demonstrates analytically that accounting conservatism combined with rapid growth in intangible assets can dramatically distort the associations between aggregate financial statement data and equity value. For example, if the firm’s investments in intangible assets are sufficiently intense, reported losses can be negatively, not positively, associated with equity values. Hand (2003c) confirms these counterintuitive predictions for intangible-intensive Internet companies. He further demonstrates that a solution to the problem of distorted relations between equity values and aggregate financial statement data for intangible-intensive firms is to replace book equity and net income with their key components—individual or major categories of assets, liabilities, revenues and expenses.

\textsuperscript{8} Ye and Finn (2000) derive a log-linear model of equity value by assuming that the log of one plus the return on equity follows an AR(1) process and net dividends are zero. Beatty, Riffe and Thompson (2001) derive a log-linear valuation model under the assumptions that stock valuation is first-degree homogenous in underlying valuation drivers, that accounting constructs measure such valuation drivers with multiplicative measurement error that is conditionally lognormal, and that the unconditional distribution of stock values is either diffuse or lognormal.
This type of substitution prevents the associations between intangible assets/expenses and equity value from contaminating the associations between tangible assets/expenses and equity value. In essence, using individual financial statement data items rather than aggregated book equity and net income removes the restriction that the accounting for all assets, liabilities, revenues, and expenses be equally biased or unbiased.9

4.2 The model of returns to venture capital investments

The returns model begins by taking first-differences of equation (1):

\[ \Delta \text{PREMV}_{ik} = \sum_{j=1}^{F} \theta_j \Delta \text{LFS}_{fik} + \sum_{g=1}^{G} \gamma_g \Delta \text{LNFS}_{gik} + \Delta \varepsilon_{ik}, \]  

(2)

Since \( \text{PREMV} \) is the product of the pre-money shares outstanding, \( \text{SHSPRE} \), and the pre-money price per share, \( \text{PRICE} \), the log change in pre-money valuations between rounds \( k-1 \) and \( k \) is the sum of the log return \( LRET \equiv \Delta \ln(\text{PRICE}_k/\text{PRICE}_{k-1}) \) and the log change in pre-money shares outstanding \( \Delta \text{PREMSHS} \equiv \Delta \ln(\text{SHSPRE}_k/\text{SHSPRE}_{k-1}) \). Substituting into equation (2) yields:

\[ LRET_{ik} = \sum_{j=1}^{F} \theta_j \Delta \text{LFS}_{fik} + \sum_{g=1}^{G} \gamma_g \Delta \text{LNFS}_{gik} - \Delta \text{PREMSHS}_{ik} + \Delta \varepsilon_{ik}. \]  

(3)

The empirical returns model that I estimate refines equation (3) in several ways. First, I restrict \( FS \) and \( NFS \) to those items of financial statement data and non-financial statement information that Hand (2003a) reports have significant coefficients. I then add one additional variable to \( \Delta \text{LNFS} \), namely an indicator for whether the lead investor is the same in rounds \( k-1 \) and \( k \). This is designed to capture the view among venture capitalists that the same lead investor two rounds in a row is a negative valuation signal, since a strongly performing firm would elicit demand from new investors to take the lead investor position in the current financing round.

These changes simplify the model and reduce the number of financial statement and non-financial statement information variables from \( F \) to \( F^* \) and \( G \) to \( G^* \). Next, I add to equation (3) a third category of explanatory variables that I term risk factors, denoted \( \text{RISK} \). The \( N \) variables in the set \( \text{LRISK} \) comprise the log of firm size, denoted \( \text{LSIZE} \), the log of the firm’s book-to-market

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9 For example, the immediate expensing of internally generated R&D assets means that the coefficient on net income will be a blend of a positive marginal association between R&D and equity value (arising from R&D being an asset), and a negative marginal association between cost of sales or other true expenses and equity value.
ratio, denoted \( LBM \), the log of firm age and the log changes in public and private equity market biotech indices. Since the latter two variables are part of \( LNFS \), \( G^* \) further declines to \( G^{**} \) and \( N \) declines to \( N^* \). I then replace log returns with log excess returns by subtracting the log riskfree rate over the round-to-round window, \( LRF \), from both the dependent variable, \( LRET \), and the log changes in public and private equity market biotech indices. I denote the excess log venture capital return as \( LEXRET \), and the riskfree-adjusted set of \( LRISK \) variables as \( LEXRISK \) (noting that \( LRF \) is not subtracted from the log of firm age). Finally, I include an intercept and allow the coefficient on \( \Delta LPREMSHS \) to deviate from \(-1\).

In total, these adjustments yield the following empirical specification:

\[
LEXRET_{ik} = \beta + \pi_1 LSIZE_{i,k-1} + \pi_2 LBM_{i,k-1} + \sum_{n=1}^{N^*} \phi_n \Delta LEXRISK_{nk} + \sum_{f=1}^{F^*} \theta_f \Delta LNFS_{fk} \\
+ \sum_{g=1}^{G^{**}} \gamma_g \Delta LNFS_{gk} - \delta \Delta LPREMSHS_{ik} + e_{ik}.
\]

Within the framework of equation (4), hypothesis H1 predicts that \( \pi_1 < 0 \) and \( \pi_2 > 0 \). Estimating equation (4) separately for the venture capital market and the public equity market, hypothesis H2 predicts that \( N^* + F^* + G^{**} > 0 \) and H3 predicts that \( \{N^*, F^*, G^{**}\} \) will be smaller in the venture capital market than in the public equity market. Hypothesis H4 predicts that the coefficient \( \phi \) on the log change in the public biotech index will be smaller in the venture capital market than in the public equity market.

5. Data

The data used to test hypotheses H1, H2, and H3 are derived from Hand (2003a). This section describes the major elements of the database, which combines venture capital equity valuations, financial statement data and non-financial statement information for 193 U.S. biotechnology companies over 1992–2003.

Venture capital values are used to compute returns and firm size. As shareholders’ equity reported in firms’ financial statements is negative 46% of the time, book-to-market ratios are computed using total assets. Fama and French (1992, table III) report very similar inferences if book-to-market ratios are computed using total assets instead of book equity. Beyond these primary variables, a rich set of potential market-wide, investor-specific, and firm-specific factors
are computed using a wide variety of financial statement data and non-financial information.

The database is large, not unduly clustered in time, and rich in different kinds of information. It contains a wide variety of financing points (Series A through Series H rounds, plus many public valuation points) spanning firms that successfully and unsuccessfully filed to go public. The database’s main limitation is that it does not contain venture capital valuations for firms that did not file to go public because they went bankrupt, merged, or chose to remain private. I address the inferential concerns that this selection bias might create in section 6.1.

5.1 Equity valuation data

Venture capital market valuations were purchased from Recombinant Capital (Recap), a West Coast consulting firm that specializes in collecting and selling information on biotechnology companies (www.Recap.com). Recap has gathered what it indicates is a full set of round-by-round financings for each of over 600 biotech companies, beginning in the early 1980s. Recap’s equity valuation histories are compiled mainly from IPO filing documents and the SEC filings of companies that acquire biotech firms.¹⁰ The valuation histories are based on primary preferred and common share issuances from the date of founding until the most recent equity financing or other share issuance (which may be after a successful IPO). Preferred shares are converted into common at the ratios specified in the financing agreements.

Equity valuations in the public equity market were obtained from online sources such as www.yahoo.com and www.siliconinvestor.com. Three post-IPO valuation dates were used, namely three months after the first, second, and third fiscal year-ends following the IPO offering date (if an IPO occurred, since not all biotech firms in the sample that filed to go public successfully accomplished an offering).

5.2 Financial statement data

For those firms in Recap’s database that filed to go public, pre-IPO financial statement data were collected from S-1 and 424B documents when available online at www.sec.gov. This exploits the fact that when a firm files to go public, it has to provide five years’ worth of audited

¹⁰ The data items in Recap’s valuation file consist of company name, the type of financing round (e.g., Founding, Series A, IPO, etc.), the category of the round (e.g., Founder/Insider, Venture, Corp. Private, etc.); the date the round was filed (that is, begun); the date the round was concluded; the amount of dollars raised in the round, if any; the price per share of that round’s financing; the post-money valuation; the number of shares involved (included infrequently); and the names of up to three investors, with the first investor being the lead investor in the round.
(albeit coarse) historical financial statement data.\textsuperscript{11} This is critical for assessing the relation between returns and book-to-market ratios because information on book value or total assets can only be obtained from firms’ financial statements at an IPO filing. Private firms are not required to disclose financial statement data and rarely do so voluntarily, especially when they are young. Post-IPO financial information for this study was taken from firms’ 10-Ks.

On a firm-by-firm basis, each year’s financial statement data were matched where possible with the first—and only the first—pre-money valuation following the fiscal year-end, as long as the valuation date was less than a year beyond the fiscal year-end.\textsuperscript{12} This process yielded 481 pairs of venture capital valuations and 441 public market valuations that were accompanied by financial statements from the preceding fiscal year, spanning a total of 193 firms. No set of annual financial statements was matched with more than one pre-money valuation. To be considered usable, a firm’s cash balance, SG&A expense, and R&D expense had to be positive.\textsuperscript{13}

The financial statement items in the database consist of three primary components of total shareholder equity—cash, noncash assets and long-term debt—and the main components of biotech firms’ net income, namely annual revenues, cost of sales, SG&A costs and R&D expense. Long-term debt includes capitalized lease obligations. Revenue is the sum of collaborative, contract, grant, license, research, and product revenues. In addition to these recognized numbers, I recorded the (unrecognized) degree of stock option dilution, defined as the number of shares under option divided by the number of shares outstanding. Stock option data are sometimes missing because firms are only required to provide three years of pre-IPO-filing stock option data in their S-1 or 424B-4 filings. To account for this, an indicator variable is included in the regressions, set equal to one if stock option data are missing and zero otherwise. Missing stock option dilution observations were reset to zero.

\textsuperscript{11} I am unaware of any other systematic, large-sample source of financial statement data for pre-IPO companies. Noting that “accounting data for private firms is unavailable,” Gompers (1995) uses SIC industry averages from Compustat for each venture capital-funded firm in his analysis of the determinants of the duration of, and funding amounts provided to, venture-backed firms.

\textsuperscript{12} For example, if a firm with a calendar year-end filed to go public on 11/5/98, and had Series A, B, and C rounds on 1/6/96, 10/27/96 and 12/5/97, the Series A and Series C would be usable, but the Series B would not because it is the second financing in 1996. In this design, only the first financing in 1996 can be matched with financial statements for the year ended 12/31/95 because it not possible to know how the financing on 1/6/96 affected financial statements as of 10/27/96. The strength of this approach is that no private equity market valuations are matched to ‘financing-contaminated’ financial statements. The limitation is that the gap between the valuation financing date and the preceding fiscal year-end can be as little as a few days and as long as almost a year.

\textsuperscript{13} A biotech firm that has no cash, or no SG&A, or no spending on R&D is highly unusual. Approximately 2\% of the observations were deleted as a result of these restrictions.
5.3 Non-financial statement information

In order to include as many as possible of the variables identified by entrepreneurial finance as relevant to venture-backed biotech firms’ pre-money values, a substantial amount of non-financial statement information was gathered. The following was collected on a firm-by-firm basis, as of the pre-money valuation date:

[1] The age of the firm. Prior research suggests that older firms are less risky (Gompers and Lerner, 1999).

[2] The level of the AMEX Biotechnology Index. Publicly traded biotech equity values are a gauge of the economic prospects of the biotech sector as a whole (Lerner, 1994a).

[3] The level of the Sand Hill Biotechnology (SHB) Index of the value of privately held and financed biotech stocks. The SHB Index is a proprietary, unbiased index of the venture capital value of pre-IPO biotech companies developed by Sand Hill Econometrics, Inc.

[4] The degree of equity dilution created by the current financing round, defined as the number of shares issued to new investors divided by the number of pre-money shares outstanding. This variable measures the degree to which the venture capital market is imperfect in that the demand for equity is less than perfectly elastic (Gompers and Lerner, 2000b; Hand, 2003a).

[5] Whether a venture capital financing round was led by a corporate investor. Gompers and Lerner (1999) find that corporate investors assign higher pre-money valuations when investing in private equity financings than do private equity funds, either because corporations perceive there to be strategic synergies available, or because corporations typically engage in less monitoring and business development than do private equity funds and therefore earn a lower expected return on their investment.

[6] The number and scope of the patents filed by the firm. Lerner (1994a) argues that intellectual property is a young biotech company’s most valuable asset.


[8] Indicator variables that measure the Series identity of the financing round. Unlike the VentureOne database used in most prior studies, the Recap database codes the Series of the financing round—that is, whether the round is Series A, Series B, etc.—rather than the life-stage of the firm.

5.4 Descriptive statistics

Table 1 reports descriptive statistics on the major financial statement and non-financial information items for the sample of 193 U.S. biotechnology firms.¹⁴ Venture capital financings

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¹⁴ This section and tables 1 and 2 draw on Hand (2003a).
are spread over the period 1992–2001, and public market valuation dates are distributed over the eight-year period 1996–2003 (panel A). Most biotech firms file to go public quite rapidly, mainly between four and six years after they were founded (panel B). The IPO filing date for the median firm occurs during preclinical testing and/or Phase I trials (see figure 1), although a few firms take much longer to file to go public. Most sample companies are in pharmaceutical preparations (SIC 2834) or commercial, physical and biological research (SIC 8731). Despite this concentration, sample firms comprise a total of 22 different 4-digit SIC codes. Of firms, 47% had their headquarters in California at the time of the IPO filing and 14% were in Massachusetts. Headquarter clustering arises because California and Massachusetts have many top universities with star scientists on their faculties (Zucker, Darby and Brewer, 1998).

In table 2, I provide a more detailed view of venture-backed firms than that obtainable from intra-market pooled data. The median values of various financial statement and non-

Pre-money valuations increase as firms mature within the venture capital market, although at a decreasing rate (table 2). Valuations all but triple once the firm is in the public

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15 Such financings include investments of common equity, private placements, and debt-related financing such as bridge and convertible notes. These can occur anywhere in the firm’s pre-IPO life, whereas Series C financings never precede Series B financings, etc.

16 A substantial body of research concludes that the equity values established at IPOs are associated with a number of anomalies (e.g., Shiller, 1990; Ritter, 1991; Ritter and Loughran, 1995, 2002; Purnanandam and Swaminathan, 2003; Yetman, 2003). There is also cause for concern as to whether equity values computed using the price range in the prospectus or the final offer price are arrived at in an arms-length manner, given the collusive behavior that has been attributed to underwriters (e.g., Ritter, 2000).
market, most likely because firms raise a substantial amount of cash at their IPO and going public removes an illiquidity discount of between 15% and 40% (Houlihan Valuation Advisors/VentureOne, 1998). Raw round-to-round returns, computed by first-differencing the observations in table 2, decline as firms mature within the venture capital market and into the public equity market. Because the IPO is not used as a valuation date, the first public returns are calculated from three months after the first fiscal year-end following the IPO to 12 months later. The median length of the venture capital market return interval is 14 months, only slightly larger than the uniform 12-month interval for public market returns (not reported in table 2).

A similarly increasing pattern is observed for virtually all financial statement items except core income, which decreases steadily because of small revenues and large expenditures on SG&A and R&D. Book-to-market ratios remain low during the time that firms are private venture-backed entities; of the 481 observations in the underlying pre-money valuation database, only 1% have a book-to-market ratio greater than one. Consistent with firms’ investment opportunity sets becoming smaller as firms mature, median asset-to-equity value ratio increase from 0.10 at Series A rounds, to 0.16 at Series C rounds, to 0.21 at Series F rounds, to 0.40 at the end of the first year after an IPO and 0.46 at the end of the third year after an IPO.

Firm age on average rises as the funding Series increases (see table 2).\(^{17}\) The median gap between the date on which the pre-money valuation is established and the end of the preceding fiscal year is always four months or less, and is smallest for Series A and largest for the IPO. The closeness of the financial statements to the valuation date mitigates the potential concern that financial statement data are stale by the time the firm’s current round of financing is undertaken, and are staler the earlier the round. The median level of the public market AMEX Biotech Index and the private market Sand Hill Biotech Index each rise steadily as firms mature. Equity dilution created at the current financing round declines from a high of 46% in Series A rounds to 17% in Series \(\geq F\) rounds, while the probability that the lead investor is a corporation steadily increases. The median number of patents filed and issued and the number of the firm’s strategic alliances all increase monotonically as firms mature.

\(^{17}\) One exception is that the median age of Series B financings is slightly less than that of Series A financings. Closer examination of this anomaly indicated that this was not due to data errors but arose by chance because the procedure by which valuations and financial statement data are combined does not guarantee that average age will be increasing in the Series level. It is also the case that sometimes a firm’s first financing is labeled as Series B.
6. Regressions

6.1 Econometric methods

Several econometric issues arise in estimating equations (1) and (4). The first is that the presence of temporally overlapping returns makes it unlikely that the assumptions of homoscedastic and serially independent errors will be satisfied in either equation if OLS is used in a pooled time-series cross-section regression. I therefore estimate both the pre-money valuation and the round-to-round returns models using Newey and West’s (1987) covariance matrix and Hansen’s (1982) GMM approach. This accommodates both serial dependence and conditional heteroscedasticity in regression residuals and has a small loss of precision relative to OLS, should errors in fact be homoscedastic and serially uncorrelated (Davidson and MacKinnon, 1993). Inferences are unchanged if OLS standard errors are used instead.

A second potential concern arises from restricting the sample to firms successful enough to file for an IPO. While this is needed to obtain firm-specific book values, it also carries inferential risks. For example, measured valuations and returns are almost certainly upward-biased, because valuations are only observed when a firm receives new financing, is acquired, or goes public—events that are more likely when the firm has been successful (Cochrane, 2003). More importantly, coefficients on the determinants of pre-money valuations and round-to-round returns may be biased. I address these concerns in the following ways.

First, the focus of this study is on the slope coefficients in equation (4), not the intercepts. As such, selection biases that only affect the mean level of returns can be safely set aside. Second, in their study of the impact of fund inflows on private equity valuations, Gompers and Lerner (2000a) find that using Heckman’s (1976) two-stage method to correct for selection bias has little impact on the magnitude or the significance of their independent variables.18

Third, the dataset I use is a truncated sample in that no valuation histories are collected for firms that do not file for an IPO, i.e., firms that are bought out, terminate, or continue without new private equity capital. The standard result of truncating on variable $y$, when the true relation between $y$ and $x$ is linear, is to bias toward zero the slope coefficient in an OLS regression of observed $y$ on observed $x$. I therefore argue that if anything, the slope coefficients on the

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18 Gompers and Lerner (2000a) estimate the probability that VentureOne, their data provider, had information about the valuation in the financing round. They then seek to explain the determinants of the valuation after adjusting for that probability. To do the same thing as they did would require purchasing data—preferably specific to the biotech sector—from a third-party vendor such as VentureOne. Cost constraints made this infeasible in this study.
Determinants of returns will be biased toward, not away from, zero. Using Bayesian techniques in the context of public market mutual funds, Stambaugh (2003, table 3) finds a similar result.

Lastly, because I estimate equations (1) and (4) using data that are pooled across financing rounds, I initially included financing round indicators in pre-money valuation regressions, and financing step-up indicators in round-to-round return regressions. Step-up indicators are set to one if the Series identifier of the current round is larger than the Series identifier of the prior round. Including step-up indicators should mitigate bias on slope coefficients that would otherwise arise when different rounds have different mean values of the dependent variable (Maddala, 1977, figure 9.2). However, because only one of the thirteen coefficients estimates on these indicators was reliably nonzero, they are not included in the reported regressions.

6.2 Venture capital market pre-money equity value regression

Regression #1 of table 3 reports the results of estimating equation (1) for venture capital pre-money equity values. By design, the results reported for regression #1 are very similar to those in Hand (2003a) because the independent variables are restricted to only the subset of variables that Hand (2003a) finds to be significant. Variables that Hand (2003a) found not to be statistically significant—and which are therefore not included in table 3—are revenues, cost of sales, SG&A expense, and all but one Series of the indicators. With only one exception (the scope/breadth of patents filed), coefficient signs in regression #1 are strongly consistent with the expectations that I now turn to outline.

<< Insert Table 3 here >>

The findings of Lerner (1994a), Gompers and Lerner (2000b), and Seppä (2003) predict that the coefficient on the AMEX Biotechnology Index of publicly traded biotech stocks will be positive because it is a gauge of the economic prospects of the biotech sector as a whole. A similar reasoning applies to the Sand Hill Biotechnology (SHB) Index of the value of privately held and financed biotech stocks. The GAAP definitions of assets and liabilities suggests that the coefficients on cash and noncash assets will be positive, and the coefficients on long-term debt and stock option dilution will be negative. I expect a positive coefficient on R&D because the bulk of the benefits from R&D emerge in future periods, and a negative coefficient on stock
dilution due to the unrecognized liability that this variable represents. The coefficient on the degree of equity dilution created by the current financing round is predicted to be negative to the extent that imperfections in the venture capital market lead to the less than perfectly elastic demand for equity (Gompers and Lerner, 2000a). Following Lerner (1994a), I predict that the number and scope of patents filed by the firm will be positively related to pre-money equity values. Based on findings in Nicholson, Danzon and McCullough (2003), I expect that the total number of a firm’s strategic alliances will also be positively related to pre-money equity values.

6.3 Venture capital market round-to-round returns regression

The same sign predictions as in regression #1 apply to the log first differences of each regression #1 variable in regression #2.19 In addition, I predict that firm age will be an idiosyncratic risk factor that is not fully diversifiable and will carry a negative coefficient because younger firms are more uncertain in almost every aspect than are more mature firms.20 The coefficient on the indicator for whether the lead investor is the same in the current and prior round is predicted to be negative. Venture capitalists see the same lead investor two rounds in a row to be an unfavorable valuation signal, since a well-performing firm would elicit demand from new investors to be the lead investor in the current financing round. Per equation (3), the coefficient on the round-to-round growth in pre-money shares should equal –1.

Hypothesis H1 predicts that the coefficients on firm size and book-to-market ratios will be negative and positive, respectively. Regression #2 shows strong support for these predictions. The coefficient estimate on firm size is –0.12 (t-statistic = –3.8), and the coefficient estimate on firm book-to-market ratio is 0.16 (t-statistic = 3.3). The magnitude of these estimates implies that at the means of the independent variables, a one standard deviation increase in log firm size leads to a decrease in the average round-to-round return of 16%, while a one standard deviation increase in log book-to-market leads to a 25% increase in the average round-to-round return.

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19 Indeed, strictly speaking the coefficients on the first-differenced variables in regression #2 should be the same as the coefficients on the pre-differenced variables in regression #1 if the observations used in regression #2 are a random sample of those used in regression #1.

20 Another reason is that venture capital funds often voluntarily restrict their investments to one or two Series. For example, a venture capital fund may invest in only the very earliest stages of a firm’s life (e.g., Series A and B) because the fund’s general partners have substantial expertise in the business issues that arise at that life-stage.
Hypothesis H2 predicts that at least one other slope coefficient will have the predicted sign (excluding the growth in pre-money shares). Inspection of regression #2 shows that excess log round-to-round returns to venture capital investments in biotech companies are explained by many factors beyond firm size and book-to-market ratios. In all, returns are reliably explained by no fewer than ten additional variables, of which two are risk-related, three are based on financial statement data, and five are items of non-financial statement information. The OLS regression adjusted $R^2$ is 36%. As predicted, beyond firm size and book-to-market risk, venture capital returns are negatively related to firm age and positively related to the return on publicly traded biotech stocks. The beta on the AMEX biotech return is 0.28, with a t-statistic of 4.7, indicating that the estimate is quite precise. This estimate is similar to the value of 0.30 found by Cochrane (2003, table 4) for firms in the Health Care sector. It is also close to the value of 0.32 found on the level of the index in regression #1. In contrast, the beta estimate on the Sand Hill venture capital biotech index is not reliably different from zero in regression #2.

Insofar as financial statement data are concerned, three of the six financial statement variables in regression #2 have coefficient signs that are reliably in the predicted direction. The logarithmic growth rates in cash, noncash assets, and spending on R&D are all positively associated with returns. However, the coefficient estimates on the growth rates in long-term debt, stock dilution and the indicator for missing stock option data are all insignificant.

In terms of non-financial statement information, venture capital returns are negatively related to the growth in the dilution created at financing dates. Although the slope coefficient is much smaller than that in regression #1, it indicates that returns are affected by the demand for equity in the venture capital market. Also, as predicted, returns are higher (lower) if the lead investor in the current (prior) financing round is a corporation rather than a venture fund, and also lower if the lead investor in the current and prior round is the same. However, the growth in the number and scope of patents filed and the number of a firm’s strategic alliances are unrelated to returns. Last, returns are negatively related to the growth in shares outstanding, but although the sign is negative, the magnitude of the estimated coefficient is reliably larger than –1.

21 Prior work has found both larger and smaller betas. Using quarterly returns on the private equity portfolio of Warbug, Pincus during 1972–1995, Gompers and Lerner (1998, exhibit 4) report a beta on the value-weighted NYSE/AMEX/NASDAQ return of 1.44. In contrast, in a large-sample regression of log changes in firm-specific pre-money values on the log change in venture capital inflows and stage-of-life and industry indicators, Gompers and Lerner (2000a, table 9) find betas on the log change in market-wide indices of between 0.02 and 0.08. In general, betas computed from log (nonlog) returns yield lower (higher) betas (Cochrane, 2003, table 7).
6.4 Venture capital market versus public equity market returns

To test hypotheses H3 and H4, I estimate a further regression. Regression #3 shares the same structure as regression #2, but uses public equity returns for the subset of firms in table 3 that completed an IPO (table 4). Returns are computed from three months after the first fiscal year-end following the IPO to 12 months later, and three months after the second fiscal year-end following the IPO to 12 months later. Not all variables included in regression #2 are available in public equity markets. Neither the beginning nor the end of the return window in the public equity market are dates on which firms raised new equity financing, so the growth in the degree of equity dilution created by financings is not defined. For similar reasons, none of the indicator variables that derive from the identity of the lead investor are defined.

The results of estimating regression #3 support hypothesis H3 (see table 4). Specifically, of the nine factors priced in venture capital returns for which data is available in the public market, only three are priced during the initial years that sample firms trade publicly. The substantial reduction in the number of priced factors is firmly consistent with the proposition that the public equity market is less imperfect than its private counterpart.

Finally, the results in table 4 also lend strong support to H4. The beta on the excess log return on the AMEX biotech index is 0.28 (t-statistic = 4.7) in regression #2, but a much larger 1.38 (t-statistic = 1.38) in regression #3. The difference of 1.10 in betas is highly significant (p-value < 0.001). Such an increase in beta moving from the more imperfect venture capital market to the less imperfect public equity market parallels the finding in international finance that the beta on the world stock return rises when previously segmented and somewhat imperfect emerging markets liberalize and integrate into the much less imperfect world capital markets (Bekaert and Harvey, 1995, 2000).

6.5 Robustness tests

The results reported in tables 3 and 4 are robust to a variety of perturbations. Very similar results obtain if firm size is measured using total assets in place of equity value, or if the log of the ratio of long-term debt to equity value is added to control for the “missing” portion of book equity that is excluded by defining book-to-market ratios using total assets rather than...
shareholder equity. No differences in inference arise if the regressions include indicator variables for the main four-digit SIC codes 2834, 2836 and 8731 or for the two most common states in which firms’ headquarters reside, California and Massachusetts. Taking into account the varying lengths of the return windows by including the length of the return window as an additional explanatory variable has immaterial effects on the estimated regression: the coefficient on the length of the return window, while positive, is insignificant. Inferences (other than those pertaining to magnitudes) are unchanged if rank regressions are estimated instead of log-linear regressions.

6.6 Caveats and limitations

Beyond the obvious uncertainty as to the generalizability of results derived from only biotech firms, this paper has two main threats to validity—selection bias and omitted variable bias. Although I argued in section 4.3 that selection bias likely works against observing regression slope coefficients that are consistent with my predictions, this is not guaranteed. Caution should therefore be exercised in generalizing the results to all private equity financings. Insofar as omitted variables are concerned, although this study has gone to substantial lengths to include many of the variables found by prior work in entrepreneurial finance to explain variation in the level of firms’ pre-money equity valuations, there may be factors omitted that are correlated with the included variables, therefore biasing the coefficients on and inferences obtained from the included variables.

7. Conclusions

In this paper I have used the unsnooped setting of biotech firms in the U.S. venture capital market to address two research questions. First, how are firm size and firm book-to-market ratios priced in the cross-section of venture capital returns, and why? Second, what effects do the distinctive features of the venture capital market have on returns, and why?

I hypothesized that firm size and market-to-book ratios will be priced negatively and positively, respectively, because they are proxies for state variables that describe how the systematic part of firm risk changes through time as firms optimize their investment and growth opportunities (Berk, Green and Naik, 1999). My empirical results for U.S. biotech companies during 1992–2003 support this hypothesis. Moreover, I argued that other explanations for why
firm size and book-to-market ratios are priced in the cross-section of public equity returns predict that these factors will not be priced in the cross-section of venture capital returns.

I then proposed that the distinctive feature of the venture capital market is that it is more imperfect than the public equity market. This leads to under-diversification. From this, I proposed that idiosyncratic risks will be priced in venture capital returns, and more so than in public equity returns. I further hypothesized that the magnitude of the loading on the return to publicly traded stocks will be larger in the public equity market than in the venture capital market. My results are consistent with each of these hypotheses.

In conclusion, this paper contributes to several streams of research. I add to the asset pricing literature by showing in a distinctive, new and unsnooped setting that firm size and book-to-market ratios are related to the returns to firm-specific venture capital investments. Moreover, my results support the Berk, Green and Naik (1999) model of the dynamic relations between returns and firms’ investment opportunities. I also contribute to the recently emerging empirical literature that documents the impacts of market frictions on the pricing of idiosyncratic risk(s), and to the literature in entrepreneurial finance that seeks to understand the drivers of equity value in private equity markets. My results shed light on the effects of market structure on equity returns, and echo results found in the international finance literature on emerging capital markets. Finally, I contribute to the value relevance literature in accounting by showing that certain financial statement data are associated with returns in a setting where financial statements might be thought to be entirely value irrelevant.
References


D.C.: Board of Governors of the Federal Reserve System.


Heckman, J.J., 1976. The common structure of statistical models of truncation, sample selection and limited dependent variables and a simple estimator for such models. *Annals of Economic and Social Measurement* 5, 475-492.


Discovery and Preclinical Testing: The drug development process usually begins with the scientific discovery of a gene or other biological pathway involved in a disease. Discovery can take 2–10 years. From discovery, a target for therapeutic intervention is established. Preclinical tests are conducted in the lab using individual cells or sometimes animals to evaluate the safety and potential for effectiveness in humans. If the target is determined to be legitimate, the company files an Investigative New Drug (IND) application with the FDA for clearance to begin testing on humans. Even after these first few years of research and testing, however, most new drug candidates will never make it to the market.

Phase I Trials: Human testing begins. The purpose of a Phase I trial is to use a small number of patients to establish basic safety and maximum dosage parameters.

Phase II Trials: This stage of clinical study is much more involved, requiring many months to plan, set up and recruit trial participants. Phase II is conducted on a larger group of patients with the targeted disease to study the efficacy of the drug at various doses and confirm its safety. They typically use blinding and placebo controls to achieve scientifically sound results. Phase II often lasts two years, and sometimes a drug will undergo multiple Phase II trials for different indications (for example, to treat different types of cancer). This may be the most critical phase in terms of sorting winners from losers. As a rule of thumb, drugs that complete Phase II and move on to Phase III have about a 50% success rate of reaching the market, though some studies suggest the rate is higher.

Phase III Trials: These tests are designed with a specific endpoint—a measurable result that clearly demonstrates success in combating the targeted disease. The endpoint must be agreed upon by the FDA as an outcome that will lead to marketing approval. The trial involves a large group from the targeted patient population and uses controls such as double-blinding (neither patient nor doctor knows who is getting a placebo). Multi-center trials are common to show that results are reproducible when administered in different clinical settings. This pivotal phase often lasts two to three years from initial design to study completion, and here again it is common for drugs to undergo more than one Phase III trial for different indications or to support different therapy combinations.

FDA Approval Process: If a drug successfully completes Phase III, the company gathers all of its clinical data and files an application for marketing approval with the FDA. It often takes three to six months just to prepare the application. Another six to twelve months can pass before an FDA advisory panel reviews the application and makes a recommendation. This advisory panel has expertise in the drug’s specific area of therapeutic or disease characteristics, and its recommendation for denial or approval is normally followed by the FDA (though another six to twelve months can pass before that happens).

Modified from an article by James Hale (http://www.theonlineinvestor.com/industries.phtml?content=is_bio2)
Table 1

**Descriptive statistics on 481 venture capital market valuations and 449 public equity market valuations spanning 193 U.S. biotechnology firms, 1992–2003**

Venture capital observations are the subset of U.S. firms in Recombinant Capital’s pre-IPO biotech valuation database that met three criteria: The firm filed to go public; its filing document(s) were available online at [www.sec.gov](http://www.sec.gov); and the valuation date was less than twelve months after a pre-IPO-filing fiscal year-end and was the first financing event after that fiscal year-end. Public equity market observations are dated three months after each of the first three fiscal year-ends following a completed IPO, where such dates exist.

Panel A: Distribution of valuation dates

<table>
<thead>
<tr>
<th>Year</th>
<th>Private</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>1992</td>
<td>15</td>
<td>0</td>
</tr>
<tr>
<td>1993</td>
<td>29</td>
<td>0</td>
</tr>
<tr>
<td>1994</td>
<td>46</td>
<td>0</td>
</tr>
<tr>
<td>1995</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>1996</td>
<td>77</td>
<td>0</td>
</tr>
<tr>
<td>1997</td>
<td>70</td>
<td>8</td>
</tr>
<tr>
<td>1998</td>
<td>67</td>
<td>49</td>
</tr>
<tr>
<td>1999</td>
<td>60</td>
<td>71</td>
</tr>
<tr>
<td>2000</td>
<td>52</td>
<td>71</td>
</tr>
<tr>
<td>2001</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>2002</td>
<td>0</td>
<td>78</td>
</tr>
<tr>
<td>2003</td>
<td>0</td>
<td>74</td>
</tr>
</tbody>
</table>

Panel B: Number of years from firm founding to IPO filing

<table>
<thead>
<tr>
<th>Years</th>
<th># firms</th>
<th>Years</th>
<th># firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 to 1 year</td>
<td>0</td>
<td>7 to 8 years</td>
<td>14</td>
</tr>
<tr>
<td>1 to 2 years</td>
<td>4</td>
<td>8 to 9 years</td>
<td>14</td>
</tr>
<tr>
<td>2 to 3 years</td>
<td>12</td>
<td>9 to 10 years</td>
<td>6</td>
</tr>
<tr>
<td>3 to 4 years</td>
<td>23</td>
<td>10 to 11 years</td>
<td>5</td>
</tr>
<tr>
<td>4 to 5 years</td>
<td>41</td>
<td>11 to 12 years</td>
<td>6</td>
</tr>
<tr>
<td>5 to 6 years</td>
<td>42</td>
<td>12 to 13 years</td>
<td>2</td>
</tr>
<tr>
<td>6 to 7 years</td>
<td>22</td>
<td>13 to 15 years</td>
<td>2</td>
</tr>
</tbody>
</table>

Panel C: Sample firms’ 4-digit SICs

<table>
<thead>
<tr>
<th>4-digit SIC</th>
<th>SIC industry description</th>
<th># firms</th>
<th>% firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>2834</td>
<td>Pharmaceutical preparations</td>
<td>61</td>
<td>32%</td>
</tr>
<tr>
<td>8731</td>
<td>Commercial, physical and biological research</td>
<td>49</td>
<td>25%</td>
</tr>
<tr>
<td>2836</td>
<td>Biological products (except diagnostic substances)</td>
<td>20</td>
<td>11%</td>
</tr>
<tr>
<td>3845</td>
<td>Electomedical and electrotherapeutic apparatus</td>
<td>12</td>
<td>6%</td>
</tr>
<tr>
<td>2835</td>
<td><em>In vitro</em> and <em>in vivo</em> diagnostic substances</td>
<td>11</td>
<td>6%</td>
</tr>
<tr>
<td>All others</td>
<td>Various (representing 17 four-digit SICs)</td>
<td>40</td>
<td>20%</td>
</tr>
</tbody>
</table>

Panel D: State in which firm headquarters were located at the time of the IPO filing

<table>
<thead>
<tr>
<th>State</th>
<th># firms</th>
<th>% firms</th>
</tr>
</thead>
<tbody>
<tr>
<td>California</td>
<td>90</td>
<td>47%</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>27</td>
<td>14%</td>
</tr>
<tr>
<td>Pennsylvania</td>
<td>11</td>
<td>6%</td>
</tr>
<tr>
<td>All others</td>
<td>65</td>
<td>33%</td>
</tr>
<tr>
<td></td>
<td>Venture capital market funding round</td>
<td>Public equity market year</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------------------------------------</td>
<td>--------------------------</td>
</tr>
<tr>
<td></td>
<td>Series A</td>
<td>Series B</td>
</tr>
<tr>
<td>Valuation data ($ mil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-money equity value</td>
<td>$ 6.3</td>
<td>15</td>
</tr>
<tr>
<td>Round-to-round raw return (median)</td>
<td>n.app.</td>
<td>38%</td>
</tr>
<tr>
<td>Round-to-round raw return (mean)</td>
<td>n.app.</td>
<td>124%</td>
</tr>
<tr>
<td>Financial statement data (preceding fiscal year; $ mil)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td>$ 0.2</td>
<td>1.5</td>
</tr>
<tr>
<td>Noncash assets</td>
<td>$ 0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Long-term debt</td>
<td>$ 0</td>
<td>0.1</td>
</tr>
<tr>
<td>Revenue</td>
<td>$ 0.03</td>
<td>0</td>
</tr>
<tr>
<td>Cost of sales</td>
<td>$ 0</td>
<td>0</td>
</tr>
<tr>
<td>Selling, general and admin. costs</td>
<td>$ 0.6</td>
<td>0.8</td>
</tr>
<tr>
<td>Research and development expense</td>
<td>$ 0.9</td>
<td>1.3</td>
</tr>
<tr>
<td>Core income</td>
<td>$ –0.9</td>
<td>–1.8</td>
</tr>
<tr>
<td>Financing raised at valuation date</td>
<td>$ 5.6</td>
<td>6.0</td>
</tr>
<tr>
<td>Total assets ÷ pre-money equity value</td>
<td>0.10</td>
<td>0.17</td>
</tr>
<tr>
<td>Non-financial statement information</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age at valuation date (yrs)</td>
<td>2.6</td>
<td>2.5</td>
</tr>
<tr>
<td>Fiscal year-end to valuation date (yrs)</td>
<td>0.18</td>
<td>0.34</td>
</tr>
<tr>
<td>AMEX Biotech Index (public market)</td>
<td>137</td>
<td>137</td>
</tr>
<tr>
<td>Sand Hill Biotech Index (private market)</td>
<td>494</td>
<td>551</td>
</tr>
<tr>
<td>New equity dilution at financing date</td>
<td>46%</td>
<td>28%</td>
</tr>
<tr>
<td>Probability of corporate lead investor</td>
<td>0.08</td>
<td>0.12</td>
</tr>
<tr>
<td>Number of patents filed</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Number of patents issued</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Scope of patents filed</td>
<td>0</td>
<td>0.67</td>
</tr>
<tr>
<td>Number of strategic alliances</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td># observations</td>
<td>39</td>
<td>89</td>
</tr>
</tbody>
</table>
Notes

1. Venture capital market observations comprise the subset of U.S. firms in Recombinant Capital’s (www.recap.com) pre-IPO biotech valuation database that met three criteria: The firm filed to go public; its filing documents were available online at www.sec.gov; and the valuation date was less than twelve months after a pre-IPO-filing fiscal year-end and was the first financing event after that fiscal year-end. Public equity market observations are equity values three months after each of the first three fiscal year-ends following a completed IPO, denoted IPO+1, IPO+2 and IPO+3, respectively, where such dates exist.

2. The firm’s pre-money equity value is the value of the firm’s equity immediately after a financing round less the financing invested in the firm at that round. In the public equity market the pre-money value is the observed equity market value of common stock.

3. Raw round-to-round returns are computed using first-differences of the data described in table 1. Although it is not used in the regressions, the return in IPO+1 uses the earliest offering price revealed in an S-1 or 424B filing (or average of an offering range) as its base.

4. Financial statement data are taken from the fiscal year/year-end immediately prior to the valuation date. Financial statements where cash, SG&A or R&D are zero are excluded, as are those where the fiscal period was less than seven months—for example, the first four months of the firm’s life. Cash is cash plus marketable securities. Long-term debt includes capitalized lease obligations. Revenue is revenues summed over six subrevenues—collaborative, contract, grant, license, research, and product revenues. Core income is defined as revenue less cost of sales, SG&A and R&D. Stock option dilution is defined as the number of shares under option divided by the number of shares outstanding, where available. Stock option data may be missing because firms are only required to provide three years of pre-IPO filing stock option data in their S-1 or 424B-4 filings. Total assets ÷ pre-money equity value is my proxy for the firm’s book-to-market ratio. Total assets are used instead of book equity because total shareholders’ equity is negative for 46% of the observations in this study.

5. Financing raised at the valuation date is the money raised by the firm in the current round.

6. New equity dilution at the financing date is defined as the number of shares issued in the private equity financing round divided by the number of pre-money shares outstanding.

7. Age at valuation date is the number of years from the firm’s founding to the valuation date.

8. Fiscal year-end to valuation date is the length of time in years between the end of the fiscal year-end immediately preceding the valuation date and the valuation date itself.

9. The Amex Biotechnology Index (^BTK) is an equal dollar-weighted index designed to measure the performance of a cross-section of companies in the biotechnology industry that are primarily involved in the use of biological processes to develop products or provide services. Such processes include, but are not limited to, recombinant DNA technology, molecular biology, genetic engineering, monoclonal antibody-based technology, lipid/liposome technology, and genomics. The BTK Index was established with a
Table 2 (continued)

bench mark value of 200 on October 18, 1991. The BTK Index is rebalanced quarterly based on closing prices on the third Friday in January, April, July and October to ensure that each component stock continues to carry approximately equal weight in the index.

10. The Sand Hill Biotechnology (SHB) Index is a proprietary, periodic, timely, value-weighted, and unbiased index of the venture capital value of pre-IPO privately funded biotech companies developed by Sand Hill Econometrics of Palo Alto, CA. The SHB Index had a benchmark value of 100 in January, 1989. In dollar terms it covers virtually all private biotech companies in the United States that have raised money from outside investors since 1987, and the valuation events used to construct the Index include funding rounds, IPOs, acquisitions, liquidations, and shutdowns. The SHB Index addresses the measurement problems unique to venture investing, namely intermittent pricing and selection bias. The Index is built from individual company data, not venture-fund data, because company-level data allow for the measurement of value at a point in time and for statistical correction for selection bias. Sand Hill Econometrics’ methods correct for bias in reporting of value for known deals and for bias in the likelihood of companies dropping out of available data sources. Companies doing poorly are less likely to report value and more likely to be left out of subsequent systematic capture of funding round or shutdown information. Using the bias-corrected data on company values, Sand Hill Econometrics builds the Index with tools akin to those used for repeat-sales indices of houses and other assets.

11. The probability of a corporate lead investor is the fraction of financings at a given round Series that is led by a corporate rather than venture fund lead investor indicator.

12. The number of patents filed is the number of patents that had been filed as of the valuation date and that were issued by the U.S. Patent Office as of 11/1/03. Source: www.uspto.gov.

13. The scope of patents filed as of the valuation date is defined as the cumulative number of distinct four-digit International Patent Classification classes into which the firm’s filed patents are assigned as of the valuation date, divided by the number of patents the firm had filed for as of the valuation date. Source: www.uspto.gov.

14. The number of strategic alliances is the sum of the firm’s upstream and downstream alliances in place at the valuation date. Source: www.recap.com.
Table 3
Log-linear pooled regressions of venture capital pre-money equity values and round-to-round excess returns on hypothesized economic determinants for U.S. biotech firms, 1992–2003

Dependent variables are the log of the firm’s pre-money equity value in the venture capital market (regression #1) and the excess log round-to-round venture capital market return (regression #2). The independent variables are the set of proposed economic determinants described in sections 4.1 and 6.2 (regression #1) and sections 4.2 and 6.3 (regression #2). In regression #1, continuous variables are log-transformed levels, while in regression #2 they are the first-differences of regression #1’s variables (i.e., logarithmic growth rates).

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Predicted sign on coefficient</th>
<th>Regression #1</th>
<th>Regression #2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Log pre-money equity value</td>
<td>Round-to-round excess log return</td>
</tr>
<tr>
<td>Intercept</td>
<td></td>
<td>4.71 (13.1)***</td>
<td>2.31 (3.5)***</td>
</tr>
<tr>
<td>Risk factors:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Firm size (pre-money equity value)</td>
<td>–</td>
<td>–0.12 (–3.6)***</td>
<td></td>
</tr>
<tr>
<td>Book-to-market ratio</td>
<td>+</td>
<td>0.16 (3.5)***</td>
<td></td>
</tr>
<tr>
<td>Firm age</td>
<td>–</td>
<td>–0.11 (–2.1)**</td>
<td></td>
</tr>
<tr>
<td>AMEX public market biotech index</td>
<td>+</td>
<td>0.32 (3.5)***</td>
<td>0.28 (4.7)***</td>
</tr>
<tr>
<td>Sand Hill venture capital biotech index</td>
<td>+</td>
<td>0.17 (1.7)*</td>
<td>–0.07 (–0.3)</td>
</tr>
<tr>
<td>Financial statement data:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cash</td>
<td>+</td>
<td>0.12 (5.4)***</td>
<td>0.09 (3.5)***</td>
</tr>
<tr>
<td>Noncash assets</td>
<td>+</td>
<td>0.18 (5.6)***</td>
<td>0.06 (2.0)**</td>
</tr>
<tr>
<td>Long-term debt</td>
<td>–</td>
<td>–0.05 (–4.1)***</td>
<td>–0.01 (–1.1)</td>
</tr>
<tr>
<td>Research &amp; development expense</td>
<td>+</td>
<td>0.17 (3.9)***</td>
<td>0.12 (3.0)***</td>
</tr>
<tr>
<td>Missing stock option data [indicator]</td>
<td>–</td>
<td>–0.27 (–3.2)**</td>
<td>–0.40 (–0.7)</td>
</tr>
<tr>
<td>Stock option dilution</td>
<td>–</td>
<td>–1.54 (–4.1)***</td>
<td>0.34 (0.6)</td>
</tr>
<tr>
<td>Non-financial statement information:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demand elasticity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New equity dilution at financing date</td>
<td>–</td>
<td>–1.28 (–13.6)***</td>
<td>–0.42 (–3.5)***</td>
</tr>
<tr>
<td>Investor identity</td>
<td></td>
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</tr>
<tr>
<td>Corporate lead investor at t [indicator]</td>
<td>+</td>
<td>0.20 (3.1)***</td>
<td>0.23 (3.1)***</td>
</tr>
<tr>
<td>Corporate lead investor at t–1 [indicator]</td>
<td>–</td>
<td>–0.20 (–3.2)***</td>
<td></td>
</tr>
<tr>
<td>Same lead investor at t and t–1 [indicator]</td>
<td>–</td>
<td>–0.13 (–2.6)***</td>
<td></td>
</tr>
<tr>
<td>Patents and alliances</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of patents filed</td>
<td>+</td>
<td>0.07 (2.7)***</td>
<td>–0.05 (–1.0)</td>
</tr>
<tr>
<td>Scope of patents filed</td>
<td>+</td>
<td>–0.23 (–3.3)***</td>
<td>–0.01 (–0.1)</td>
</tr>
<tr>
<td>Number of strategic alliances</td>
<td>+</td>
<td>0.09 (2.6)***</td>
<td>–0.03 (–0.4)</td>
</tr>
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<tr>
<td>Increase in shares at round t–1</td>
<td>–</td>
<td>–0.59 (–3.4)***</td>
<td></td>
</tr>
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<td># observations</td>
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<td>481</td>
<td>288</td>
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<td># firms</td>
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<td>193</td>
<td>154</td>
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<tr>
<td>OLS regression adj. R²</td>
<td></td>
<td>76%</td>
<td>36%</td>
</tr>
<tr>
<td>Residual standard deviation</td>
<td></td>
<td>0.56</td>
<td>0.41</td>
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</tbody>
</table>
Table 3 (continued)

Notes

1. Venture capital market observations comprise the subset of U.S. firms in Recombinant Capital’s (www.recap.com) pre-IPO biotech valuation database that met three criteria: The firm filed to go public; its filing documents were available online at www.sec.gov; and the valuation date was less than twelve months after a pre-IPO-filing fiscal year-end and was the first financing event after that fiscal year-end.

2. The firm’s pre-money equity value is the value of the firm’s equity immediately after a financing round less the financing invested in the firm at that round.

3. In regression #2, raw round-to-round returns are computed using first-differences of the data employed in regression #1. See equations (1) – (4) in the text. Excess returns are log raw returns less the log riskfree return over the return horizon.

4. Asymptotic Z-statistics are shown in parentheses and are computed using Newey and West’s (1987) heteroskedastic- and autocorrelation-consistent standard errors. Single, double, and triple asterisks denote coefficient estimates that are reliably nonzero at the 5%, 2.5% and 1% levels, respectively, under a one-tailed test of the coefficient sign prediction. The significance level of the intercept is computed under a two-tailed test.

5. All dollar variables $Z$ are log-transformed according to $\log_e[Z+1]$ where $Z \geq 0$ is in $000$s. The following nondollar variables $Y$ are log-transformed according to $\log_e[Y+1]$: stock option dilution, the level of the AMEX biotech index, the level of the Sand Hill biotech index, new equity dilution at the financing date, the number of patents filed, the scope of patents filed, and the number of strategic alliances. Firm size, book-to-market ratios, and firm age are log-transformed according to $\log_e[X]$.

6. Firm size is the firm’s pre-money equity value at the beginning of the return window. The book-to-market ratio is computed using total assets instead of book equity because total shareholders’ equity is negative for 46% of the observations in this study.

7. The Amex Biotechnology Index (^BTK) is an equal dollar-weighted index designed to measure the performance of a cross-section of companies in the biotechnology industry that are primarily involved in the use of biological processes to develop products or provide services. Such processes include, but are not limited to, recombinant DNA technology, molecular biology, genetic engineering, monoclonal antibody-based technology, lipid/liposome technology, and genomics. The BTK Index was established with a benchmark value of 200 on October 18, 1991. The BTK Index is rebalanced quarterly based on closing prices on the third Friday in January, April, July and October to ensure that each component stock continues to carry approximately equal weight in the index.

8. The Sand Hill Biotechnology (SHB) Index is a proprietary, periodic, timely, value-weighted, and unbiased index of the venture capital value of pre-IPO privately funded biotech companies developed by Sand Hill Econometrics of Palo Alto, CA. The SHB Index had a benchmark value of 100 in January, 1989. In dollar terms it covers virtually all private biotech companies in the United States that have raised money from outside investors since 1987, and the valuation events used to construct the Index include funding rounds, IPOs, acquisitions,
liquidations, and shutdowns. The SHB Index addresses the measurement problems unique to venture investing, namely intermittent pricing and selection bias. The Index is built from individual company data, not venture-fund data, because company-level data allow for the measurement of value at a point in time and for statistical correction for selection bias. Sand Hill Econometrics’ methods correct for bias in reporting of value for known deals and bias in the likelihood of companies dropping out of available data sources. Companies doing poorly are less likely to report value and more likely to be left out of subsequent systematic capture of funding round or shutdown information. Using the bias-corrected data on company values, Sand Hill Econometrics builds the Index with tools akin to those used for repeat-sales indices of houses and other assets.

9. Financial statement data are taken from the fiscal year/year-end immediately prior to the valuation date. Financial statements where cash, SG&A, or R&D are zero are excluded, as are those where the fiscal period was less than seven months—for example, the first four months of the firm’s life. Cash is cash plus marketable securities. Long-term debt includes capitalized lease obligations. The missing stock option data indicator is set to one if no stock option data are available (this occurs in 27% of venture capital valuation observations), and zero otherwise. Stock option data may be missing because firms are only required to provide three years of pre-IPO filing stock option data in their S-1 or 424B-4 filings. Stock option dilution is defined as the number of shares under option divided by the number of shares outstanding. Where stock option data are missing, stock option dilution is recoded from missing to zero.

10. New equity dilution at the financing date is defined as the number of shares issued in the venture capital financing round divided by the number of pre-money shares outstanding.

11. The corporate lead investor indicator is set to one if the lead investor in the venture capital market financing round is a private or public corporation, and zero otherwise.

12. The number of patents filed is the number of patents that had been filed as of the valuation date and that were issued by the U.S. Patent Office as of 11/1/03. Source: www.uspto.gov.

13. The scope of patents filed as of the valuation date is defined as the cumulative number of distinct four-digit International Patent Classification classes into which the firm’s filed patents are assigned as of the valuation date, divided by the number of patents the firm had filed for as of the valuation date. Source: www.uspto.gov.

14. The number of strategic alliances is the sum of the firm’s upstream and downstream alliances in place at the valuation date. Source: www.recap.com.
Table 4


Dependent variables are the excess log round-to-round equity return in the venture capital market (regression #2) and the excess annual stock return in the public equity market (regression #3). The independent variables are the set of proposed economic determinants per sections 4.2 and 6.3 of the text, and detailed in the notes to table 3. Continuous independent variables are the logarithmic growth rates of the stated variables, where they exist. Regression #2 is repeated from table 3.

<table>
<thead>
<tr>
<th>Independent variables</th>
<th>Predicted sign on coefficient</th>
<th>Regression #2</th>
<th>Regression #3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td>Round-to-round excess log return</td>
<td>Annual excess log return</td>
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<tr>
<td>Intercept</td>
<td></td>
<td>2.31 (3.5)***</td>
<td>0.64 (0.6)</td>
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<td>Risk factors:</td>
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<tr>
<td>Firm size (pre-money equity value)</td>
<td>–</td>
<td>–0.12 (–3.6)***</td>
<td>0.06 (0.9)</td>
</tr>
<tr>
<td>Book-to-market</td>
<td>+</td>
<td>0.16 (3.5)***</td>
<td>0.32 (3.5)***</td>
</tr>
<tr>
<td>Firm age</td>
<td>–</td>
<td>–0.11 (–2.1)**</td>
<td>0.01 (0.1)</td>
</tr>
<tr>
<td>AMEX biotech index</td>
<td>+</td>
<td>0.28 (4.7)***</td>
<td>1.38 (7.6)***</td>
</tr>
<tr>
<td>Sand Hill biotech index</td>
<td>+</td>
<td>–0.07 (–0.3)</td>
<td>–0.07 (–0.2)</td>
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<tr>
<td>Financial statement data:</td>
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</tr>
<tr>
<td>Cash</td>
<td>+</td>
<td>0.09 (3.5)***</td>
<td>0.26 (3.1)***</td>
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<tr>
<td>Noncash assets</td>
<td>+</td>
<td>0.06 (2.0)**</td>
<td>0.05 (0.9)</td>
</tr>
<tr>
<td>Long-term debt</td>
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<td>–0.01 (–1.1)</td>
<td>–0.00 (–0.2)</td>
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<tr>
<td>Research &amp; development expense</td>
<td>+</td>
<td>0.12 (3.0)***</td>
<td>–0.03 (–0.3)</td>
</tr>
<tr>
<td>Missing stock option data [indicator]</td>
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<td>Stock option dilution</td>
<td>–</td>
<td>0.34 (0.6)***</td>
<td>1.50 (1.9)</td>
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<tr>
<td>Non–financial statement information:</td>
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<tr>
<td>Demand elasticity</td>
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<tr>
<td>New equity dilution at financing date</td>
<td>–</td>
<td>–0.42 (–3.5)***</td>
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<td>Investor identity</td>
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<tr>
<td>Corporate lead investor at t [indicator]</td>
<td>+</td>
<td>0.23 (3.1)***</td>
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<tr>
<td>Corporate lead investor at t–1 [indicator]</td>
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<td>–0.20 (–3.2)***</td>
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<tr>
<td>Same lead investor at t and t–1 [indicator]</td>
<td>–</td>
<td>–0.13 (–2.6)***</td>
<td></td>
</tr>
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<td>Patents and alliances</td>
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<td></td>
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<tr>
<td>Number of patents filed</td>
<td>+</td>
<td>–0.05 (–1.1)</td>
<td>0.16 (0.8)</td>
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<td>Scope of patents filed</td>
<td>+</td>
<td>–0.01 (–0.1)</td>
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<td>+</td>
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<td>35%</td>
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<td>Residual standard deviation</td>
<td></td>
<td>0.41</td>
<td>0.71</td>
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Notes: See the notes to table 3.