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Opportunity Cost of Capital for Venture Capital Investors and Entrepreneurs

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We use a database of recent high-technology IPOs to estimate opportunity cost of capital for venture capital investors and entrepreneurs. Entrepreneurs face the risk-return tradeoff of the CAPM as the opportunity cost of holding a portfolio that necessarily is underdiversified. For early-stage firms, we estimate the effects of underdiversification, industry, and financial maturity on opportunity cost. Assuming a one-year holding period, the entrepreneur's opportunity cost generally is two to four times as high as that of a well-diversified investor. With a 4.0 percent risk-free rate and 6.0 percent market risk premium, for the sample average, we estimate the cost of capital of a well-diversified investor to be 11.4 percent, or 16.7 percent before the management fees and carried interest of a typical venture capital fund. For an entrepreneur with 25 percent of total wealth invested in the venture, our corresponding estimate of cost of capital is 40.0 percent. Empirical results are of the same order of magnitude as estimates derived by others, using different methods, but have the advantage of being based on public data.

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I. Introduction

Investors and entrepreneurs are attracted to venture capital by the prospect of earning higher returns on their financial and human capital than they can by investing in publicly traded firms. Nonetheless, although data are sparse, studies of venture capital and entrepreneurship generally find that realized returns to venture capital investors are similar to returns on publicly traded equity and financial returns to entrepreneurs are low. Some researchers conjecture that entrepreneurs accept low financial returns because they also derive nonpecuniary benefits or because they value positive skewness of financial returns.[1] Others argue that entrepreneurs seek high financial returns but chronically are overly optimistic.[2] In any case, for their choices to be rational, entrepreneurs and venture capital investors must anticipate total returns (pecuniary and nonpecuniary) that exceed opportunity cost of capital. Hence, evidence of opportunity cost is central to understanding the investment choices.

In this paper, we develop estimates of opportunity cost of capital for well-diversified limited partners of venture capital funds and for underdiversified entrepreneurs. We base the analysis on aftermarket performance of a large sample of recent initial public offerings ("IPOs") by high-tech firms. The approach is possible because of the high level of IPO activity in the late 1990s. The period is unique in that many high-tech firms went public with extremely limited operating histories, including firms with high risks of failure, firms that had not yet generated any revenue, and firms with small numbers of employees. The sample includes many observations of pre-revenue firms and a large number of observations of firms with fewer than 26 employees. These data enable us to test whether, for early-stage firms, beta risk, total risk, and correlation with the market are related to firm size or stage of development.

After controlling for industry and various indicators of financial maturity, our estimates rely on the assumption that public and private equity are similar in beta risk. Our approach parallels the accepted

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[1] See discussion in Moskowitz and Vissing-Jørgensen (2002).

practice among public corporations of relying on market data to infer cost of capital. For public corporations, it is common to assume that the beta risk of a new project is comparable to the beta risk of public firms with projects in the same industry. Our evidence, and evidence from other studies, supports this approach. We find that the average beta risk of newly public high-tech firms is approximately equal to that of the overall market and that beta risk is positively related to firm age and size.

For entrepreneurs, we provide for the effects of underdiversification and human capital investment by estimating total risk. Here, we rely on the assumption of equal variance for private and early stage public firms. For sample firms, total risk averages almost five times as high as market risk. The ratio of total risk to market risk decreases with firm age and size. Allowing for the entrepreneur's ability to allocate wealth between the venture and a market index, we estimate that cost of capital generally is two to four times as high as for well-diversified investors such as the limited partners of venture capital funds.

II. Motivation and Methodology

A. *Returns to Venture Capital Investing*

A number of researchers have inferred required returns on venture capital investments by studying realized returns of venture capital funds. Based on a variety of sources and time periods, these studies find gross-of-fee returns that have ranged from 13 to 31 percent.[3] Over the twenty years ending with calendar 2001, the arithmetic average of annual net-of-fee returns to fund investors was 17.7 percent.[4] In contrast, for the same period, the arithmetic average return to investing in the S&P 500 was 15.6 percent.

It is not clear whether this historical two-percent return premium represents expected compensation for investing in venture capital or is simply an artifact based on limited data. Because venture capital is a recent phenomenon, historical returns reflect only a few years of (possibly

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[2] Using survey data, Cooper, Woo, and Dunkelberg (1988) find that entrepreneurs are overly optimistic. Bernardo and Welch (2001) offer a sorting explanation for why over-confidence persists among entrepreneurs.

[3] See, e.g., Ibbotson and Brinson (1987), Martin and Petty (1983), Bygrave and Timmons (1992), Gompers and Lerner (1997), Venture Economics (1997, 2000). In a recent study, after correcting for bias due to unobservability

idiosyncratic) activity. Furthermore, the cross-sectional distribution of returns is highly skewed, with a few large wins offsetting many losses. Consequently, returns on past investments, while informative, are not a reliable basis for estimating required rates. Furthermore, studies of historical returns provide little evidence of how returns vary by venture size, stage of development, industry, or market conditions.

Our approach is distinct from previous studies, and is based on the recognition that the predominant suppliers of venture capital and private equity are well-diversified institutions or wealthy individuals who limit such investments so as to not adversely impact their overall portfolio liquidity. The implication is that required returns are governed by the same portfolio theory reasoning that public corporations routinely rely on to infer cost of capital for new projects.

B. *Returns to Entrepreneurship*

Evidence of returns to entrepreneurial activity is even more limited. In a recent study, Moskowitz and Vissing-Jørgensen (2002) use data from the *Survey of Consumer Finances* and other information, to document that private equity returns are, on average, no higher than returns on public equity. They conclude that a diversified public equity portfolio offers a more attractive risk-return tradeoff. Hamilton (2000) uses survey data to compare earnings differentials in self-employment and paid employment and suggests that self-employment results in lower median earnings. He concludes that entrepreneurs appear to be willing to sacrifice earnings for nonpecuniary benefits and the prospect of a positive windfall.

Because an entrepreneur must commit a significant fraction of financial and human capital to a single venture, the entrepreneur's cost of capital is affected by total risk, correlation with risk of the entrepreneur's other investment opportunities, and achievable diversification.[5] To estimate cost of capital, we assume the entrepreneur holds a two-asset portfolio, consisting of investments in the venture and the market. We examine how the relative weights of these assets affect portfolio risk. The approach to estimating cost of capital assumes that the entrepreneur can forego the venture and duplicate total

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of returns on poorly performing investments, Cochrane (2001) finds geometric average realized returns of 5.2 percent on venture capital investments. However, due to skewness, the arithmetic average is 57 percent.

[4] As reported by Venture Economics, the estimate is based on its sample of several hundred venture capital funds.

[5] The entrepreneur's underdiversification is similar to that of a public corporation executive whose compensation includes illiquid stock options or an employee whose pension assets include illiquid firm equity. Meulbroek (2002)

portfolio risk by leveraging an investment in the market. We first estimate the cost of capital of the entrepreneur's portfolio and then solve algebraically for the opportunity cost of investing in the venture. Estimates are based on evidence of total risk and correlation derived from a sample of high-tech IPOs.

Several researchers use similar portfolio-based approaches to infer hurdle rates for underdiversified investments in new ventures. Heaton and Lucas (2001) model and calibrate the return that would make a household indifferent between investing in a three-asset portfolio consisting of a private firm, a public equity index, and T-bills, or a two-asset portfolio of the public equity index and T-bills. Assuming a reasonably risk averse entrepreneur, a zero correlation between private and public equity, and an allocation of wealth between the venture and the market, they estimate that the entrepreneur's hurdle rate for investing in the venture would be about 10 percent above the public equity return. Brennan and Torous (l999) and Benartzi (2000) also study the hurdle rate for holding an underdiversified position in a single asset and reach similar conclusions.

Our analysis differs from these studies in two respects. First, instead of basing hurdle rate estimates on risk aversion, we derive market-based estimates of opportunity cost. When entrepreneurs are constrained to hold only two assets (equity in the venture and a market index) our estimates represent lower bound hurdle rates over all risk aversion levels. When the entrepreneur also can hold cash, Garvey (2001) shows that our estimates are lower bounds over a broad class of risk aversion coefficients and that the estimates approximately equal the exact hurdle rates over a narrower class of reasonable coefficients.

Second, we estimate total risk and correlation between firm returns and market returns for newly public high-tech firms in various industries and of various financial and operational maturities. In contrast, the models of Heaton and Lucas, Brennan and Torous, and Benartzi are calibration studies that are not tested with empirical data. The studies are based on assumed correlations between the over-weighted asset and the market index. In spite of using a different approach, our estimates reflect underdiversification risk premia that are similar to the estimates from the calibration studies.

C. *The Advantages of Risk-Based Estimates of Opportunity Cost of Capital*

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and Hall and Murphy (2002) use models similar to ours to examine the efficiency of including illiquid firm equity in

To estimate opportunity cost of venture capital, we apply the CAPM to empirical measures of systematic risk for newly public firms in industries where venture capital investing is common. We then extend the approach to estimate opportunity cost for entrepreneurs. Because the analysis is based on empirical measures of *risk* rather than on realized *returns*, the approach can be used at any time, with forward-looking projections of market risk premia, risk-free rates, and correlation, to develop estimates of expected returns, just as estimates can be developed for new projects of public corporations.

Because the sample includes only firms that choose to go public, the issue of selection bias arises. However, in contrast to studies of realized returns, our focus on risk is less subject to bias. Empirically, we find no systematic differences in the betas of firms at early development stages versus later stages. Further, our estimates of beta are consistent with those based on private firm returns (see Cochrane). Conceivably, selection is a more serious concern for total risk, as firms that go public may be less risky than firms with similar characteristics that do not. If so, reliance on public firm data may result in underestimates of cost of capital for entrepreneurs. However, as our sample includes pre-revenue firms, and very small firms, there is little reason to anticipate materially different risk levels between our sample and non-public firms with similar characteristics.

III. Opportunity Cost of Capital for Venture Capital Investors

A. Estimating Cost of Capital with the Risk-Adjusted Discount Rate Approach

We use the CAPM to estimate cost of capital for investments by well-diversified investors. In the familiar risk-adjusted-discount-rate form of the CAPM, the investor's cost of capital, $r_{Venture}^{Investor}$, is:

$$(1) \qquad r_{Venture}^{Investor} = r_F + \rho_{Venture,M}\left(\sigma_{Venture}^{Investor} / \sigma_M\right)\left(r_M - r_F\right) = r_F + \beta_{Venture}\left(r_M - r_F\right)$$

where r_F is the risk-free rate, r_M is the expected return on investment in the market portfolio, $\rho_{Venture,M}$ is the correlation between venture returns and market returns, $\sigma_{Venture}^{Investor} / \sigma_M$ is the well-diversified investor's equilibrium standard deviation of venture returns divided by the standard deviation of market returns, and $\beta_{Venture}$ is the venture's beta risk. Equation (1) assumes the investor requires no

retirement assets of underdiversified employees.

additional return for bearing liquidity risk. All variables are defined over the expected holding period, i.e., from investment to harvest. The standard deviation measures (and, therefore, the measures of beta) are based on *equilibrium* holding period returns for a well-diversified investor, where equilibrium refers to the point where the present value of expected future cash flow is correct for a well-diversified investor. That is, for a zero-NPV investment of one dollar, with expected return, $r_{Venture}^{Investor}$, the investor's standard deviation of holding period returns, $\sigma_{Venture}^{Investor}$, equals the standard deviation of the venture's expected cash flows, $\sigma_{C_{Venture}}$, divided by the one-dollar present value. Consequently, reliance on beta risk rests on the assumption that the investor (i.e., a public firm stockholder or a limited partner of a venture capital fund) is well diversified.

B. Endogeneity of Equilibrium Risky Rates of Return

The equilibrium solution of Equation (1) requires that the opportunity cost and standard deviation of returns be determined simultaneously. In practical applications, CAPM users circumvent this problem by inferring betas from data on comparable publicly traded securities. The certainty-equivalent form of the CAPM provides an alternative when data on comparable firms are not available. The alternative uses the standard deviation of cash flows instead of the equilibrium standard deviation of holding period returns.

Equation (2) is the certainty-equivalent form of the CAPM:

$$(2) \qquad PV_{Venture}^{Investor} = \frac{C_{Venture} - \frac{\rho_{Venture,M}\,\sigma_{C_{Venture}}}{\sigma_M}(r_M - r_F)}{1 + r_F}.$$

where $C_{Venture}$ is the expected harvest cash flow, and $\sigma_{C_{Venture}}$ is the standard deviation of harvest cash flows. By using an estimate of $\sigma_{C_{Venture}}$ developed, for example, from a model of the venture, and an estimate of $\rho_{Venture,M}$ derived from data on comparable public firms, $PV_{Venture}^{Investor}$ can be estimated. The investor's opportunity cost of capital is determined as $C_{Venture} / PV_{Venture}^{Investor} - 1$.

Venture capital limited partnerships segregate returns to the general partner from returns to limited partners. The general partner's carried interest typically is 20 percent of total fund returns after invested capital has been returned to the limited partners, plus a management fee equal to about 2.5 percent of committed capital. The gross-of-fee return represents the cost to an entrepreneurial venture of raising capital from a venture capital fund. The spread between the gross-of-fee return and the net-of-fee return represents the general partner's return to effort.

C. Reliance on the CAPM

Empirical studies find that single factor models cannot explain historical returns as well as multi-factor models. Fama and French (1995), for example, estimate a multi-factor model where firm size and book-to-market value also are statistically significant. However, Jagannathan and Wang (1996) estimate a conditional version of the CAPM where beta can vary over business cycles. In their model, the Fama-French factors no longer are significant and the unconditional CAPM implied by their conditional specification is not rejected by the data. Reliance on the CAPM for making prospective estimates of cost of capital is consistent with Jagannathan and Wang. Our estimates of beta, total risk, and correlation with the market are developed from a sample that spans a six-year period from roughly the beginning to the end of the "dot-com" episode. Hence, the estimates effectively are averages over a business cycle and are appropriate for prospective estimation when one is agnostic about future states of the economy.

D. Venture Capital Fund Hurdle Rates and Underdiversification

As a venture capital fund is a conduit for investing in projects, its underdiversification is no different than that of any public firm. Our assumption that limited partners are well diversified is supported by the fact that most venture capital is provided by large institutions that allocate only small fractions of total resources to venture capital.[6] Even the venture capital investments of a limited partner often are diversified, with investments spread across dozens of funds.

Historical realized returns to venture capital investing are consistent with financial economic theory. Evidence on public venture capital portfolios and venture capital-backed public firms indicates that the betas range from less than 1.0 to around 2.0. For a broad sample, Cochrane (2001) reports maximum likelihood estimates of 0.88 to 1.03 against the S&P500 and 0.98 to 1.29 against the NASDAQ Index. Average realized returns, net of fees and carried interest, also have been similar to market averages.

E. Illiquidity of Venture Capital Investments

Illiquidity can affect cost of capital for three reasons: First, a large illiquid investment can result in inefficient diversification. Second, by investing in an illiquid asset, an investor could be foregoing a return to information trading. Third, even if an illiquid investment represents a negligible fraction of a portfolio, it could, together with other illiquid holdings, contribute to aggregate portfolio illiquidity that is costly for the investor. Our estimates incorporate the effect of illiquidity on portfolio diversification, but we do not adjust the estimates to compensate for foregone information trading or aggregate portfolio illiquidity.

Section IV shows that opportunity cost of capital for investing in venture capital or private equity increases with illiquidity and with underdiversification. The longer a party is constrained to hold an inefficiently diversified portfolio, the greater is the consequence of underdiversification on the certainty-equivalent value of the portfolio at harvest. Additionally, the entire penalty for underdiversification is assessed against the over-weighted asset in the portfolio (i.e., the investment in the venture). Thus, illiquidity, as reflected by expected time until harvest, affects the entrepreneur's cost of capital. Because, by assumption, investment in the venture is a trivial fraction of the well-diversified investor's portfolio, illiquidity does not affect the investor's cost of capital.

In our estimates of cost of capital for well-diversified investors, we make no adjustment for illiquidity due to information asymmetry. Illiquidity could adversely affect an investor's return on effort devoted to information trading. However, the limited partners who choose to invest in venture capital funds are passive and are unlikely to be sacrificing returns to their own information-trading efforts. Furthermore, when illiquidity results from information asymmetry, the asymmetry reduces expected

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[6] For example, *Pensions & Investments* reports that, as of 2001, the top 200 defined benefit pension plans had 4.4

harvest cash flows. Thus, also adjusting the discount rate would result in double counting. Evidence of higher average returns on market assets with low liquidity does not imply that the marginal investors in the assets require a return premium. Because observed returns on illiquid assets are averages of the excess returns to informed investors and normal returns to uninformed investors, the averages are higher than opportunity cost. Hence, while average returns do measure the cost of capital of the issuer, they cannot be interpreted as measuring cost of capital for uninformed investors.

Nor do we adjust the well-diversified investor's opportunity cost for costs associated with aggregate portfolio illiquidity. The required return to the marginal well-diversified investor in illiquid assets depends on the relative supply and demand of illiquid claims. As long as passive investors in venture capital are well diversified and have adequate liquidity in their other holdings, they bear no significant cost for sacrificing liquidity with respect to a small fraction of their assets.

IV. Opportunity Cost of Capital for Entrepreneurs

While, as cited, several researchers develop hurdle rates for entrepreneurial investments based on risk aversion, no previous research addresses the entrepreneur's opportunity cost. Risk tolerance cannot justify an investment that is expected to provide total benefits that are less than the expected pecuniary return of an equally-risky investment in the market. Underdiversification makes quantitative consideration of opportunity cost central to the decision to become an entrepreneur and to the design of financial contracts between entrepreneurs and investors.

A. The Full-Commitment Case

Consider the opportunity cost of capital for an entrepreneur who makes a "full commitment" to a venture. Full commitment is a hypothetical extreme case, where a prospective entrepreneur must choose between committing all financial and human capital irrevocably to a venture or, alternatively, holding all wealth in a market portfolio. We derive the entrepreneur's minimum required return as the opportunity cost of investing in a well-diversified portfolio that is leveraged to achieve total risk equivalent to that of a full commitment to the venture. We use the Capital Market Line ("CML") that underlies the CAPM to

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percent of total assets in private equity, including 0.9 percent in venture capital (www.pionline.com).

estimate the entrepreneur's opportunity cost. Because an entrepreneur who must make a full commitment cannot offset venture risk by diversifying, the entrepreneur's cost of capital depends on total risk. Thus, the entrepreneur's cost of capital, $r_{Venture}^{Entrepreneur}$, is:

$$(3) \qquad r_{Venture}^{Entrepreneur} = r_F + \left(\sigma_{Venture}^{Entrepreneur} / \sigma_M\right)\left(r_M - r_F\right),$$

where $\sigma_{Venture}^{Entrepreneur} / \sigma_M$ is the entrepreneur's equilibrium standard deviation of venture returns divided by the standard deviation of market returns.

Because the standard deviation measures are based on the *entrepreneur's* equilibrium holding period returns, equation (3) cannot be used directly with public firm data to estimate opportunity cost. We address the problem by modifying the certainty-equivalent CAPM model. Equation (4) is the certainty- equivalent model that is consistent with the equilibrium result from equation (3).

$$(4) \qquad PV_{Venture}^{Entrepreneur} = \frac{C_{Venture} - \frac{\sigma_{C_{Venture}}}{\sigma_M}(r_M - r_F)}{1 + r_F}$$

Below, we use data for comparable public firms to infer $\sigma_{C_{Venture}}$ as a percent of expected harvest cash flow, and to estimate the underdiversification risk premium.

B. The Partial-Commitment Case

Entrepreneurs can undertake new ventures without committing their entire financial and human capital. Still, they must commit large fractions of total wealth and must remain substantially underdiversified. To examine how underdiversification affects cost of capital, we consider an entrepreneur who can allocate a portion of wealth to a well-diversified portfolio. We use a three-step process to estimate cost of capital. First, we estimate the equilibrium standard deviation of returns on the entrepreneur's total portfolio. Second, we use the CAPM to estimate portfolio opportunity cost. Third, we set portfolio opportunity cost equal to the weighted average of the opportunity costs of the market and the venture, and solve for cost of capital of the entrepreneur's investment in the venture.

The standard deviation of returns of the entrepreneur's two-asset portfolio is given by:

(5) $$\sigma_{Portfolio} = \sqrt{x_{Venture}^2 \sigma_{Venture}^2 + x_M^2 \sigma_M^2 + 2 x_{Venture} x_M \rho_{Venture,M} \sigma_{Venture} \sigma_M}$$

where $x_{Venture}$ and x_M are the fractions of the entrepreneur's *ex ante* wealth invested in the venture and the market. Substituting $\sigma_{Portfolio}$ for $\sigma_{Venture}$ in equation (3) gives the equilibrium opportunity cost of the entrepreneur's portfolio, $r_{Portfolio}$. Portfolio opportunity cost also is a value-weighted average of the opportunity costs of investments in the venture and in the market.

(6) $$r_{Portfolio} = x_{Venture} r_{Venture} + x_M r_M \; .$$

Solving equation (6) for the entrepreneur's cost of capital for investing in the venture yields,

(7) $$r_{Venture} = \frac{r_{Portfolio} - x_M r_M}{x_{Venture}} \; .$$

Assuming investment in the market is always a zero-NPV opportunity, equation (7) assigns the effects of underdiversification to the cost of capital for investing in the venture.

Because equations (5) through (7) are based on equilibrium holding period returns, they cannot be estimated directly. The standard approach of finessing simultaneity is to rely on comparable market data on holding period returns. However, partial commitment makes this approach problematic because the entrepreneur's cost of capital depends on total wealth and ability to diversify. The certainty-equivalent approach provides a solution. If the total cash flow risk of the venture financial claim can be estimated, equation (4) can be modified to value the entrepreneur's portfolio by substituting portfolio cash flow information for venture cash flow information. The entrepreneur's expected portfolio cash flow and standard deviation of portfolio cash flows are given by the following expressions:

(8) $$C_{Portfolio} = C_{Venture} + w_M (1 + r_M) \; ,$$

(9) $$\sigma_{C_{Portfolio}} = \sqrt{\sigma_{C_{Venture}}^2 + (w_M \sigma_M)^2 + 2 \rho_{Venture,M} \sigma_{C_{Venture}} (w_M \sigma_M)}$$

where w_M is the entrepreneur's *ex ante* wealth invested in a market index. For the market portion of the portfolio, we use the standard deviation of returns and value of investment in the market to infer the standard deviation of harvest cash flows. With these substitutions, equation (4) gives the value of the entrepreneur's portfolio. The present value of investment in the venture can be computed directly, by deducting the entrepreneur's investment in the market,

$$(10) \qquad PV_{Venture}^{Entrepreneur} = PV_{Portfolio}^{Entrepreneur} - w_M \, .$$

or,

$$(11) \qquad PV_{Venture}^{Entrepreneur} = \frac{C_{Portfolio} - \dfrac{\sigma_{C_{Portfolio}}}{\sigma_M}(r_M - r_F)}{1 + r_F} - w_M \; .$$

In equation (11), we treat investment in the market as a zero-NPV opportunity, and assign the effect of underdiversification to the venture. This is a measure of value based on the opportunity cost of investing in the market. It does not incorporate the entrepreneur's personal tolerance for risk. Because, based only on risk and expected return, private value cannot exceed the value of an alternative equally-risky investment in a market index, equation (11) is an upper bound on the entrepreneur's private value.

If $PV_{Venture}^{Entrepreneur} < w_{Venture}$, where $w_{Venture}$ is the entrepreneur's investment in the venture, then the NPV of the entrepreneur's total investment in the venture and the market index is negative, compared to an alternative of investing in a market index leveraged to achieve equivalent total risk. If $PV_{Venture}^{Entrepreneur} > w_{Venture}$, the portfolio is more valuable than an equally risky leveraged investment in the market. For the entrepreneur, $PV_{Venture}^{Entrepreneur} > w_{Venture}$ is necessary but not sufficient for a decision to proceed with the venture. Based on risk tolerance, the leveraged investment in the market index may, itself, not be acceptable. Thus, except for qualitative factors such as a preference for self-employment, equation (11) is an estimate of *maximum* present value.

Correspondingly, equation (11) can be solved for the minimum equilibrium required rate of return,

$$(12) \qquad r_{Venture}^{Entrepreneur} = \frac{C_{Venture}}{PV_{Venture}^{Entrepreneur}} - 1 = r_F + \frac{\left(\dfrac{\sigma_{C_{Portfolio}}}{\sigma_M} - w_M\right)(r_M - r_F)}{PV_{Venture}^{Entrepreneur}} \; .$$

Equation (11) is a way of valuing the entrepreneur's investment that relies on direct estimates of venture cash flow risk rather than the risk of holding period returns. Equation (12) merely reveals the opportunity cost of capital that is implicit in the valuation.

C. Inferring the Entrepreneur's Cost of Capital for Market Comparables

Equations (11) and (12) rely on market data only for estimates of market risk and correlation between the venture and the market. Thus, they do not permit use of a risk-adjusted discount rate approach of valuing expected cash flows. However, reliance on data of comparable public firms is possible. For an entrepreneur who must make a full commitment, equation (4) can be used, along with the opportunity cost of a well-diversified investor, to derive the following expression for the value of the entrepreneur's claim:

$$(13) \qquad PV_{Venture}^{Entrepreneur} = \frac{C_{Venture} - \dfrac{(r_{Venture}^{Investor} - r_F)}{\rho_{Venture,M}}}{1 + r_F} .$$

To illustrate use of equation (13), consider a claim on a comparable public firm, where the claim is expected to return one dollar at harvest, which, we assume, will be in one year. Suppose market risk is estimated to have an annual variance of 4.0 percent, the comparable firm beta to be 1.25 and the correlation with the market to be 0.2. If the risk free rate is 4.0 percent and the market risk premium is 6.0 percent, the investor's required rate of return, $r_{Venture}^{Investor}$, is 11.5 percent. Equation (13) shows that, for the entrepreneur, investing as a total commitment, the one-dollar risky expected cash flow is equivalent to a certain harvest-date cash flow of 0.664 dollars and has a present value of 0.638 dollars, implying that, for a full commitment, the entrepreneur's opportunity cost of capital would be 56.7 percent.

While full commitment is not feasible, the same approach can be used to value partial commitments. For an entrepreneur who can partially diversify, we use equation (11) and substitute the diversified investor's equilibrium expected cash flow for $C_{Portfolio}$, as if the investor held the same two-asset portfolio, but valued investment in the venture based on its market risk.

$$(14) \qquad C_{Portfolio} = w_{Market}(1 + r_M) + w_{Venture}^{Investor}(1 + r_F + \beta_{Venture}(r_M - r_F)),$$

where $w_{Venture}^{Investor}$ is based on the diversified investor's equilibrium valuation. We then compute the diversified investor's equilibrium total risk, $\sigma_{C_{Portfolio}}$, based on equation (9).

$$(15) \qquad \sigma_{C_{Portfolio}} = \sqrt{(w_M \sigma_M)^2 + (w_{Venture}^{Investor} \sigma_{Venture})^2 + 2\rho_{Venture,M} w_M w_{Venture}^{Investor} \sigma_M \sigma_{Venture}}$$

Equations (14) and (15) represent expected portfolio cash flows and cash flow risk inferred from public firm data. The estimates can be used in equation (10) to find the present value of the entrepreneur's investment in the venture, and in equation (12) to find equilibrium cost of capital.

Continuing the illustration, consider a hypothetical total investment of one dollar by an investor who prices only systematic risk, where \$0.60 is invested in the market portfolio and \$0.40 is invested in a public firm comparable to the venture (with beta risk of 1.25 and correlation of 0.2, as above). Based on the assumptions, the investor's expected cash return in one year is \$1.106, including \$0.660 from investment in the market and \$0.446 from investment in the comparable firm. Using equation (15) and the assumption that the annualized standard deviation of market returns is 20 percent, the annualized standard deviation of the two-asset portfolio cash flows is 53.7 percent. Employing this information in equation (11), the value of the entrepreneur's portfolio is \$0.909, reflecting the effect of underdiversification. Thus, \$0.309 is the value of the claim on the venture which pays \$0.446 in expected cash flow at harvest. In relation to the investment of \$0.60 in the market, this value accounts for 34.0 percent of the entrepreneur's total wealth. From equation (12), the entrepreneur's opportunity cost of investing in the venture is 44.5 percent. Thus, even with this degree of diversification, the entrepreneur's opportunity cost is much higher than that of a well-diversified investor. To assess an opportunity with risk characteristics similar to the public firm, an entrepreneur who anticipated committing 34.0 percent of total wealth to the venture, and placing the balance in the market could discount expected cash flows at the 44.5 percent rate.

V. Evidence on New Venture Opportunity Cost of Capital

For a well-diversified investor, equation (1) requires an estimate of the beta of the financial claim. For the entrepreneur, equations (11) through (15) require an estimate of the risk of holding period returns for a well-diversified investor and an estimate of correlation with the market.

A. Data and Method

Because we are interested in early-stage firms and in how corporate maturity and financial condition affect risk, we concentrate on newly public firms in technologically oriented industries. Results are based on eight industries that attract significant amounts of venture capital investment: Biotechnology, Broadcast and Cable TV, Communication Equipment, Communication Services, Computer Networks, Computer Services, Retail Catalog and Mail Order (including Internet), and Software. Because the data are maintained continuously and are current, Yahoo is our primary source of stock performance data. We use financial data from Compustat, supplemented with data from Market Guide.

The database includes all firms in the eight industries that went public between l995 and late 2000. We define an observation as a calendar firm-year. Because risk attributes may change with maturity, we use stock performance data from a single year to estimate the risk attributes of an observation. We match the most recent calendar year of stock price data to the most recent fiscal year of financial data. Most observations have December 31 fiscal years. Thus, stock performance for one calendar year is matched with financial data of the prior fiscal year. We retain observation for which at least 30 weeks of stock price data are available along with financial data for the corresponding fiscal year. Application of these screens results in a total of 2,623 firm-year observations. Table 1 contains the breakdown by industry.

B. Bivariate Results

Table 2 provides statistical information under headings of Calendar Year, Industry, Firm Age, Financial Condition, and Employees. We measure firm age relative to the IPO date. We also classify observations either as “from the year of the IPO” or “from years after the IPO.” Financial condition classifications correspond to stages of firm development. If the firm has no revenue during the year, it is an early-stage firm that may be engaged in research and development before start-up of operations. If the firm has revenue but income is negative, it generally is at a stage where it needs continuing external financing and may not have reached sufficient scale to sustain operations from cash flow. Some of these observations are of troubled firms, where previous years of positive income are followed by losses in the classification year. If net income is positive, the firm may be sustainable with operating cash flows, though growth still may require outside financing. We use number of employees as another measure of maturity and size. The tables include quartile data to enable sensitivity analysis. Numbers of observations for each grouping (reported in column 2) are the same for all measures of risk in the table.

Beta: The third column of Table 2 contains beta estimates using the S&P500 Index as the market proxy. Results are equilibrium equity betas for well-diversified investors. Betas would be higher for underdiversified investors due to lower valuations and higher equilibrium holding period returns, and the correspondingly higher standard deviations. We use weekly returns as a convenient way to reduce bias due to nonsynchronous trading. Most firms in our sample are early-stage and do not rely on debt financing.

The standard errors in the table can be used to make convenient inferences regarding differences in mean values.[7] Though we do not report significance tests in the table, interpretations of results are made in consideration of the statistical significance of differences in means at the 5 percent level.

Although new ventures are risky, most of the risk is idiosyncratic. Table 2 shows an overall average beta near 1.0 relative to the S&P500. The range across industries is from 0.75 to 1.24.[8] For most years, the average betas in our sample are below 1.0 relative to the S&P500. In 1995 and 1996, when high-tech stocks represent a small fraction of market capitalization, average betas are not significantly different from zero. Because market capitalization of high-tech stocks had increased by 2000 and the

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[7] The standard error of the difference between any two means is somewhat less than the sum of the standard errors. Thus, dividing the difference by the sum of the two produces a negatively biased estimate of the t-value. On the other hand, because firms are included in the sample for several years (an average of 2.6 years), the observations are not independent. Lack of independence would positively bias the t-value. As we do not make strong statements of statistical significance between groups, we do not correct for either bias.

[8] We also estimated betas and other risk statistics relative to the NASDAQ Composite Index and the PSE Technology Index and additional statistics relative to the S&P500. Results using other indexes are similar to those using the S&P500. An appendix containing the additional statistics is available on the JFQA website.

market decline in 2000 was concentrated among technology and growth firms, the high-tech attribute of the market index was stronger than in the other years.

Average betas increase significantly with age as a public firm and with firm size. Betas are higher for firms with revenue but negative income than for those with no revenue or with positive income. Only the latter difference is statistically significant at conventional levels. The pattern for financial condition suggests that, as firms mature, they transition from risk that is highly idiosyncratic to risk more closely related to the market and that market risk declines as profitably is achieved. Average betas are significantly different across some industries. However, as most betas relative to the S&P500 are close to one, the economic importance of the differences is limited. The results imply that cost of capital for venture capital investments is comparable to that of publicly-traded stocks.

Standard deviation of returns: As a basis for estimating opportunity cost for underdiversified investors, we use the returns data to estimate of total risk and correlation with the market. In column 5 of Table 2, we report statistics for the annualized standard deviation of returns for well-diversified investors. Because entrepreneurs cannot diversify fully, their equilibrium returns and the corresponding standard deviations are higher. The average annualized standard deviation of returns in our sample is 120 percent. Though not reported, differences between mean and median returns indicate positive skewness, as median returns consistently are lower than means. The means of annualized standard deviations vary significantly over years, but the variations are not systematic.

Total risk varies significantly across industries. Whereas our estimate of beta increases with firm age and number of employees, total risk generally decreases modestly with increases in age and number of employees. We also find a weak tendency for total risk to decline as financial condition improves. Firm maturity should generally correspond to declining total risk and possibly increasing market risk. Thus, the disparity between the entrepreneur's opportunity cost and that of a well-diversified investor is likely to be greatest for early-stage ventures.

Though Table 2 does not contain estimates of equilibrium standard deviations for underdiversified entrepreneurs, the results imply that higher costs of capital should be used for earlier stage ventures. However, regardless of how the data are partitioned, the mean standard deviation remains close to the 120 percent overall mean. The main exception is the high standard deviation in the year of IPO. The implication is that, for estimating total risk, factors like stage of development, financial condition, and firm size are of limited economic significance.

Total risk to market risk: In Column 7 of Table 2, we normalize total risk by the standard deviation of returns on the S&P500 Index for the year. For the full sample, total risk is more than 5.6 times as high as the risk of the S&P500 Index. The significant differences in standard deviations persist when total risk is normalized by market risk. It is noteworthy, that the ratios increase systematically over the six years of our study. The time-series is consistent with the trend toward IPOs occurring at earlier stages of development. Correspondingly, the ratio tends to be high in the year of the IPO, before the firm has achieved positive income, and where number of employees is low. Nonetheless, most means are in the range of 4.0 to 6.5 times market risk.

The results suggest that one approach to estimating opportunity cost for either a well-diversified or an underdiversified investor is to estimate total market risk, such as by using implied volatilities from options on a market index, and then using the Table 2 results to derive an estimate of normalized total risk. This estimate, combined with an estimate of correlation with the market, is a simple alternative to estimating a venture's total risk directly.

Correlation with market returns: In Column 9 of Table 2, we report correlations between returns of firm equity and the S&P500 Index. Correlations generally are low, as most new ventures are narrowly focused, with cash flows that are not sensitive to market-wide cash flows. The average correlation in our sample is 0.195. As implied by earlier results, the calendar-year means are increasing from 1995 through 2000. The means in the first two years are not significantly different from zero. Correlations with the S&P500 Index increase significantly with firm age, financial condition, and number of employees. The low correlations point to the potential for value creation by using financial contracts to shift risk to well-diversified investors.

C. Multivariate Results

In Table 3, we use regression analysis to examine the combined effects of industry, age, and financial condition. The table summarizes results for three risk attributes: standard deviation of returns, correlation with the S&P500 Index, and beta risk measured against the S&P500. Model specifications intentionally are parsimonious. We estimate intercepts and age coefficients by industry, and restrict revenue and income coefficients to be uniform across industries. While we allow estimates to vary by calendar year, a forward-looking estimate normally would be based on a representative average or a market volatility forecast. The standard deviation model includes the market standard deviation as an explanatory variable. For observations where a previous-year estimate is available, we include a lag term. For a firm's first observation, we code the lag as zero and assign a value of one to a "no lag" dummy variable.

Consistent with earlier discussion, total risk is positively related to market risk. A one-percent increase in market risk corresponds to a 1.5 percent increase in total risk. Though intercept differences usually are not significant, total risk is negatively related to firm maturity. Except for Biotechnology, the intercept is the sum of the Biotechnology intercept and the industry-interacted intercept. Similarly, the age effect is the sum of the default age coefficient and the industry interaction with age. Positive revenue is not significantly related to total risk, but positive operating income corresponds to a 3.3 percent reduction. The year variables evidence the variability of standard deviation estimates. In a forward-looking estimate, the average calendar year effect is a –7.3 percent adjustment to value derived from the other coefficients.

The correlation results indicate substantial variation across industries, though significance levels are moderate. Operating income is again significant. The effects of firm maturity vary significantly across industries. Correlations are significantly lower in years other than 2000, which is the default year. Beta risk also varies across industries and decreases with firm age. The relation with age varies considerably across industries. Beta is lower for firms with operating income, though the relation is only significant at the 10 percent level.

With regard to all three models, most of the explanatory power is associated with the random year effects. The models also suggest that total risk decreases modestly with age and financial condition, that correlation increases modestly with these factors, and that beta risk increases with age but decreases with financial condition. For estimating opportunity cost, the results provide little improvement over the bivariate results in Table 2. Consequently, reliance on the averages from this sample of early-stage public firms is likely to work well across a broad range of industries and stages of development.[9]

D. Opportunity Cost of Capital

Table 4 contains estimates for all observations and by industry and stage of development of opportunity cost for entrepreneur and well-diversified venture capital investors. The table calculations assume an annual equilibrium standard deviation of the market of 16.2 percent (based on most recent 20-year S&P500 data), and correlations and standard deviations for the groupings from Table 2. We base the estimates on an assumed risk-free rate of 4.0 percent and market rate of 10.0 percent.

Cost of capital for well-diversified investors: Based on total risk of 102.1 percent and a correlation of 0.195 with the market, the All-Observation beta, for example, is 0.99. Using our market return assumptions, opportunity cost of a well-diversified investor is 11.4 percent. The estimate is based on assumptions for the risk-free rate and market risk premium that both are below historical averages but are consistent with the current environment. In the context of a venture capital investment, or in cases where due diligence and other investments of effort are not separately compensated, cost of capital must be grossed up to compensate for investment of effort. Based on the normal 20 percent carried interest of venture capital fund managers and a 2.5 percent annual management fee, the required gross return for the All-Observations sample is about one-third higher, or 16.7 percent.

[9] To address this proposition more formally, we compared group averages with estimates derived from the regression models in Table 3. A table that shows results is available in the appendix on the JFQA website. For all data groupings, the average predicted value is similar to the true group average. The improvement in forecast accuracy from using the regression is reflected in a reduction of the standard deviations of the prediction errors, but the improvement is slight.

Cost of capital of the entrepreneur: In Table 4, we quantify the effect of underdiversification on the entrepreneur's opportunity cost. For an entrepreneur who must commit total wealth, we use equations (11) and (12), but set w_M equal to zero. For full commitments, opportunity cost is very high and varies considerably across industry and by financial maturity. Whereas the investor's cost of capital generally increases with firm maturity, the entrepreneur's generally decreases. Market risk rises, but total risk falls.

To infer realistic levels of entrepreneurial underdiversification, we considered a variety of scenarios of the entrepreneur's remaining work life, length of commitment to the venture, and financial wealth that cannot be invested in the venture. Based on that analysis, it appears unlikely that an entrepreneur could commit more than about 35 percent of total wealth to a venture. Even that would involve an irrevocable commitment of human capital for several years.[10] In the table, we assume that an entrepreneur may commit 15 to 35 percent of total wealth. For example, assuming the entrepreneur must invest 35 percent and can invest the balance in the market, we use equations (11) and (12) to estimate the entrepreneur's opportunity cost based on all observations. The resulting estimate is 45.6 percent.

The difference between the entrepreneur's cost of capital and the 16.7 percent gross-of-fees opportunity cost of diversified investors suggests the potential to create value by contracting to shift risk to the investor.[11] With 25 percent of wealth in the venture, the entrepreneur's cost of capital declines to 40.0 percent. With 15 percent, it declines to 31.1 percent. Thus, reducing the entrepreneur's investment both transfers risk to the better-diversified investor and reduces the entrepreneur's cost of capital. Yet, even when the entrepreneur's commitment represents a fairly small fraction of total wealth, the difference between the entrepreneur's cost of capital and that of a venture capital investor is substantial.

Sensitivity to assumptions: The estimates in Table 4 depend on specific assumptions about the risk-free rate and market-risk premium. For a well-diversified investor, the effects of different

[10] To determine the human capital commitment, we estimate the present value of the entrepreneur's income from continued employment until age 65. We deduct the earnings from self-employment for the length of the assumed commitment and allow for the possibility that, if the venture were to fail or the entrepreneur were to leave the venture, the previous level of income could not be achieved. We assume the difference is a stream of cash that could have been invested in the market index.

[11] Heaton and Lucas (2001) use similar reasoning to explore the potential for value to be created through contracts that shift risk to well-diversified investors and reach similar conclusions.

assumptions for either of these factors are easily assessed using the CAPM. For an underdiversified investor the effects of changing assumptions are less obvious. Based on the average of all observations, for example, increasing the risk-free rate has a slightly less than additive effect on the cost of capital. Increasing the risk-free rate by 1.0 percent increases the estimated cost of capital for an entrepreneur, with 25 percent of wealth in the venture, by 0.9 percent. For the same sample, cost of capital estimates are highly sensitive to the assumed market risk premium. Increasing the market risk premium by 1.0 percent increases the estimated cost of capital for an entrepreneur, with 25 percent of wealth in the venture, by 8.6 percent.

VI. Discussion

This paper develops a framework for evaluating investments in entrepreneurial ventures. The framework is based on applying the CAPM to determine opportunity cost of capital for well-diversified investors (such as in the limited partners of venture capital funds) and recognizing that entrepreneurs, as underdiversified investors, have opportunity costs of capital that can be substantially higher than the rates that are appropriate for well-diversified investors.

We present evidence on the parameters that determine cost of capital for entrepreneurs and well-diversified investors. The evidence, based on data for newly-public firms in eight high-tech industries, indicates that total risk averages 5 times as high as market risk, correlations with market returns are around 0.2, and equity betas are comparable to the overall market. While the total risk of early-stage firms decreases with various indicia of maturity, market risk increases.

Our findings complement results of recent studies of hurdle rates for risk-averse entrepreneurs. Using a hurdle rate or opportunity cost as a decision criterion, returns for underdiversified investments in new ventures would need to be substantially higher than returns for investing in a diversified portfolio. The evidence adds to these earlier findings, and is the only study based on empirical data for recently public high-tech firms with limited track records.

The findings indicate that the entrepreneur's cost of capital declines rapidly as the fraction of wealth that must be invested in the venture declines. However, even with modest underdiversification, the entrepreneur's cost of capital is substantially higher than that of a well-diversified investor. For reasonable levels of underdiversification and a one-year holding period, underdiversification risk premia generally are 10 to 40 percent above the cost of capital of a well-diversified investor. Even with 15 percent of wealth in the venture, underdiversification risk premia are in the 10 to 30 percent range.

Depending on the industry and maturity of the venture and the fraction of the entrepreneur's financial and human capital that is committed to the venture, we estimate that the entrepreneur's cost of capital is two to four times as high as the cost of capital for a well-diversified investor. Similarly, the entrepreneur's cost is 1.5 to three times as high as our estimate of the gross-of-fee-and-carried-interest required rate of return of venture capital funds.

The difference in cost of capital between underdiversified and well-diversified investors is an important departure from the "Law of One Price." Because the entrepreneur's cost of capital depends on total risk, opportunities exist for designing value-maximizing strategies for undertaking new ventures. Strategies that reduce the total investment, such as by shortening the time to abandonment or reducing scale or scope, can create value by reducing the entrepreneur's commitment, and hence lower the cost of capital. Holding total investment constant, contracts between entrepreneurs and investors can enhance value and can turn unacceptable ventures into attractive ones. In particular, contracts that shift risk to investors can reduce the venture's weighted average cost of capital.

Of course, differences in perception between the entrepreneur and the investor about the likelihood of success, as well as adverse selection and moral hazard, all may favor contract provisions that shift risk to the entrepreneur. Hence, choices of strategy and allocations of risk reflect a set of trade-offs that includes the cost of capital differential between the entrepreneur and the investor. More generally, our evidence points to the potentially large economic cost of illiquid employee stock and option ownership positions and to the potential for value to be created through going-public transactions.

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Table 1

Description of Sample

The sample includes all firms in eight selected industries with IPOs in 1995 through late 2000. An observation is a calendar firm-year. Observations with incomplete financial information or less than 30 weekly returns in a calendar year are omitted.

Description of Sample			
Industry	**Firms in Sample**	**Observations in Sample**	**Average Firm-Years**
Biotechnology	151	501	3.3
Broadcast and Cable TV	44	105	2.4
Communication Equipment	88	247	2.8
Communication Services	158	407	2.6
Computer Network	35	130	3.7
Computer Services	200	440	2.2
Retail Catalog And Mail Order (Internet)	19	39	2.1
Software	297	754	2.5
Total	992	2623	2.6

Table 2

Equity Risk Attributes Calculated Using the S&P500 as Market Proxy

Betas, standard deviations, and correlations for individual firm-years and the S&P500 are calculated on a calendar-year basis using weekly returns and assuming time series independence. Years with less than 30 return observations are eliminated. Results in the table are equilibrium estimates for well-diversified investors. Results for betas and standard deviations are equilibrium estimates for well-diversified investors. See Appendix for additional descriptive data.

		Beta (S&P500)		Std. Dev. of Returns		Std. Dev Firm/ Std. Dev. S&P		Correlation with S&P	
	Number of Obs.	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error	Mean	Standard Error
All Observations	2623	0.993	0.037	1.204	0.020	5.620	0.095	0.195	0.006
Calendar Year									
1995	24	-0.014	0.438	1.199	0.283	4.572	0.832	-0.136	0.121
1996	160	0.019	0.147	1.224	0.086	4.229	0.206	-0.033	0.042
1997	329	0.477	0.076	0.834	0.033	4.251	0.101	0.124	0.018
1998	476	0.798	0.095	1.042	0.030	4.992	0.098	0.209	0.014
1999	673	0.245	0.061	1.143	0.034	6.030	0.180	0.098	0.008
2000	961	1.976	0.057	1.450	0.041	6.371	0.211	0.328	0.006
Industry									
Biotechnology	501	0.747	0.068	1.039	0.031	4.780	0.131	0.149	0.013
Broadcast and Cable TV	105	0.804	0.117	0.871	0.064	4.379	0.323	0.237	0.023
Communication Equipment	247	1.157	0.107	1.199	0.050	5.554	0.214	0.215	0.019
Communication Services	407	1.019	0.091	1.035	0.039	4.880	0.173	0.241	0.014
Computer Networks	130	1.023	0.100	0.932	0.031	5.122	0.167	0.208	0.018
Computer Services	440	0.811	0.112	1.442	0.052	6.440	0.223	0.172	0.015
Catalog/Mail Order (Internet)	39	1.240	0.181	1.058	0.060	5.495	0.301	0.217	0.030
Software	754	1.202	0.079	1.368	0.050	6.386	0.257	0.200	0.011
Age (Years After IPO)									
0-1 years	1263	0.930	0.070	1.347	0.030	5.977	0.124	0.162	0.010
2-3 years	957	0.958	0.037	1.041	0.035	5.334	0.196	0.212	0.007
>3 years	403	1.270	0.061	1.141	0.027	5.180	0.123	0.259	0.010
Year of IPO (year 0)	407	0.604	0.192	2.124	0.072	7.983	0.150	0.037	0.026
Years After IPO (years 1 – 5)	2159	1.086	0.027	1.040	0.018	5.204	0.094	0.227	0.005
Financial Condition									
No Revenue	102	0.824	0.203	1.190	0.075	5.508	0.281	0.165	0.030
Revenue, Negative Income	1475	1.139	0.051	1.347	0.028	6.242	0.134	0.197	0.007
Positive Income	1033	0.821	0.055	0.995	0.028	4.720	0.124	0.200	0.010
Employees									
0 – 25	187	0.586	0.112	1.257	0.049	6.165	0.244	0.117	0.019
26 – 100	496	0.861	0.078	1.275	0.037	5.999	0.180	0.153	0.013
Over 100	1661	1.138	0.045	1.131	0.026	5.383	0.130	0.231	0.007

Table 3

Risk Attribute Regression Results

Regressions include both industry dummies for the intercept term and industry dummies interacted with the Age variable for the slope of the Age variable. Biotechnology is the baseline industry for the regressions. The baseline year is 2000. The S&P500 standard deviation is estimated from weekly returns for the contemporaneous year. Firm Age is measured as years since the IPO. Revenue equals one if the observation is associated with positive revenues and zero otherwise. Operating Income equals one if operating income is positive and zero otherwise. For the first year in a series, a binary ("No Lag") variable is included and the lagged dependent variable value is zero.

	Standard Deviation of Returns		Correlation with S&P500 Index		Beta Based on S&P500 Index	
Variable	**Coefficient**	**t Value**	**Coefficient**	**t Value**	**Coefficient**	**t Value**
Intercept (Biotech Industry, year 2000)	0.156	5.25**	0.391	6.55**	2.609	6.74**
Broadcast and Cable TV Dummy	0.011	0.25	-0.105	-1.18	-0.999	-1.73
Communication Equipment Dummy	0.028	0.91	-0.095	-1.46	-0.564	-1.33
Communication Services Dummy	0.034	1.17	-0.092	-1.50	-0.646	-1.62
Computer Network Dummy	0.018	0.38	0.140	1.44	0.969	1.53
Computer Services Dummy	0.195	6.28**	-0.283	-4.35**	-1.772	-4.18**
Retail Catalog Dummy	-0.029	-0.37	0.081	0.50	0.393	0.37
Software Dummy	0.059	2.26*	-0.142	-2.59**	-0.386	-1.09
S&P500 Std. Deviation	1.466	9.51**				
Firm Age (Biotech Industry)	-0.028	-1.66	-0.078	-2.20*	-0.599	-2.61**
Firm Age * Bdcst and Cble TV Dummy	-0.023	-0.73	0.134	2.01*	0.736	1.70
Firm Age * Comm Equip Dummy	-0.001	-0.05	0.116	2.42*	0.717	2.30*
Firm Age * Comm Services Dummy	-0.026	-1.20	0.130	2.87**	0.647	2.19*
Firm Age * CompNet Dummy	-0.004	-0.13	-0.047	-0.68	-0.400	-0.90
Firm Age * CompServ Dummy	-0.128	-5.49**	0.220	4.49**	1.291	4.04**
Firm Age * RetailCat Dummy	0.024	0.40	-0.040	-0.32	-0.173	-0.21
Firm Age * Software Dummy	-0.014	-0.73	0.130	3.27**	0.535	2.06*
1995 Dummy	-0.152	-5.27**	-0.431	-7.38**	-2.078	-5.47**
1996 Dummy	-0.107	-8.71**	-0.357	-14.45**	-2.094	-12.99**
1997 Dummy	-0.098	-11.39**	-0.216	-11.85**	-1.616	-13.59**
1998 Dummy	-0.050	-6.74**	-0.130	-8.35**	-1.221	-12.06**
1999 Dummy	-0.031	-4.74**	-0.244	-17.69**	-1.758	-19.56**
Revenue (binary)	-0.006	-0.43	-0.022	-0.78	-0.044	-0.24
Operating Income (binary)	-0.029	-5.36**	0.018	1.59	-0.134	-1.81
No Lag Dummy	0.056	7.10**	0.011	0.63	0.152	1.43
Lagged Dependent Variable	0.139	5.23**	0.182	5.22**	0.129	3.07**
Adj. r^2	0.204		0.187		0.179	

** Significant at the .01 level.

* Significant at the .05 level.

Table 4

Illustrative Opportunity Cost of Capital for Well-diversified Investors and Underdiversified Entrepreneurs

The annualized standard deviation of the market is assumed to be 16.2 percent, the annualized risk-free rate is assumed to be 4 percent, and the market return is assumed to be 10 percent. Industry-specific standard deviations and correlations with the market are representative of 1995-2000 (based on Tables 2 and 4). Beta and costs of capital are computed. Reported standard deviations are based on CAPM equilibrium for a well-diversified investor. Gross-of-fee cost of capital for well-diversified investors is based on 20 percent carried interest and 2.5 percent annual management fee. The entrepreneur's cost of capital depends on the proportion of wealth invested in the venture. The table illustrates full commitment (100 percent) and partial commitments of 35, 25 and 15 percent. Entrepreneur's cost of capital is based on equations (11) and (12) and assumes a one-year commitment.

Category Grouping	Standard Deviation	Correlation	Beta	Well-diversified Investor Cost of Capital		Underdiversified Entrepreneur Cost of Capital			
				Net	Gross	100%	35%	25%	15%
All Observations	102%	0.20	0.99	11.37%	16.72%	57.5%	45.6%	40.0%	31.1%
Industry									
Biotechnology	104%	0.15	0.78	9.78%	14.72%	60.2%	47.4%	41.2%	31.2%
Broadcast and Cable TV	87%	0.24	1.04	11.73%	17.17%	46.1%	36.2%	31.8%	25.2%
Communication Equipment	120%	0.22	1.32	13.78%	19.72%	70.7%	57.9%	51.6%	40.7%
Communication Services	104%	0.24	1.25	13.24%	19.06%	57.6%	46.4%	41.2%	32.8%
Computer Networks	93%	0.21	0.98	11.23%	16.54%	50.7%	39.8%	34.8%	27.2%
Computer Services	144%	0.17	1.22	13.07%	18.83%	96.9%	80.7%	72.1%	56.3%
Retail Cat. and Mail Order (Internet)	106%	0.22	1.17	12.64%	18.30%	59.6%	48.0%	42.4%	33.4%
Software	137%	0.20	1.37	14.15%	20.19%	87.2%	72.5%	64.9%	49.2%
Firm Age Since IPO									
Year of IPO	212%	0.04	0.39	6.91%	11.13%	291.7%	252.1%	228.9%	178.8%
1 to 5 Years After IPO	104%	0.23	1.11	12.74%	18.43%	58.0%	46.6%	41.2%	32.6%
Financial Condition									
No Revenue	119%	0.17	0.98	11.27%	16.59%	72.2%	58.4%	51.4%	39.5%
Revenue, Negative Income	135%	0.20	1.33	13.83%	19.79%	85.1%	70.6%	63.1%	49.6%
Positive Income	100%	0.20	1.00	11.37%	16.71%	55.4%	43.9%	38.5%	29.9%
Employees									
0-25 Employees	126%	0.12	0.73	9.45%	14.31%	81.0%	65.4%	57.3%	43.1%
26-100 Employees	128%	0.15	0.98	11.23%	16.53%	80.7%	65.8%	58.1%	44.6%
Over 100 Employees	113%	0.23	1.31	13.68%	19.60%	64.7%	52.7%	46.8%	37.1%