The Price of Diversifiable Risk in Venture Capital and Private Equity*

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Abstract

This paper demonstrates how the principal-agent problem between venture capitalists and their investors (limited partners) causes limited partner returns to depend on diversifiable risk. Our theory shows why the need for investors to motivate VCs alters the negotiations between VCs and entrepreneurs and changes how new firms are priced. The three-way interaction rationalizes the use of high discount rates by VCs and predicts a correlation between total risk and net of fee investor returns. We take our theory to a unique data set and find empirical support for the effect of the principal-agent problem on equilibrium private equity asset prices. (JEL G24, D82, G31)

Venture capitalists (often called VCs) are known to use high discount rates in assessing potential investments. This strategy may be just a fudge factor that offsets optimistic entrepreneurial projections, but VCs claim to use high discount rates even in internal projections. Furthermore, Cochrane (2005) looks at individual VC projects and shows that they earn large positive alphas, which suggests the use of high discount rates in pricing. In general, VCs seem overly concerned with total risk, especially considering that fund investors are well diversified. Why?

This paper answers this question with a novel theory that links the principal-agent problem to asset prices, with empirical tests of the theory on private equity fund data from 1980–2011. Our theory extends the principal-agent problem to interactions between the agent and a third party. In the venture capital arena, the principal-agent problem between an investor and a venture capitalist alters the negotiation between the venture capitalist and the entrepreneur. Although perfectly competitive investors expect zero alpha in equilibrium, the nature of the three-way interaction results in a correlation between total risk and average return even net of fees. We show that diversifiable risk can be priced in VC deals, even if the outside investors are fully diversified.

We then take our theory to a large data set of venture capital fund returns and show that there is a correlation between realized risk and investor returns, as predicted by the model: The quartile of VC funds with the greatest idiosyncratic risk has an alpha of 2.55% per quarter, whereas the lowest quartile has a per quarter alpha of -1.6%.

The trade-off between risk and incentives is a classic feature of contracts. Much of the work on this aspect of the principal-agent problem has focused on either the optimal contract (e.g., see Holmstrom and Weiss (1985) or Holmstrom and Milgrom (1987)) or on the attempt to see the resulting trade-offs empirically (see Prendergast (1999) for a survey). Our main contribution is to examine both theoretically and empirically the effect of the principal-agent problem on equilibrium asset prices.

The VC market is the ideal arena to examine the economic significance of the principal-agent problem, because the investing principals (limited partners) do not have the time or skill to become overly involved in fund management (and could potentially lose their limited liability status). Furthermore, we can see outcomes, in the form of returns, that are potentially affected by the principal-agent problem.

To bring the principal-agent problem to asset prices, we develop a simple yet novel model. The market is characterized by entrepreneurs with ideas, and outside investors who are well-diversified, but have little ability or time to screen and manage potential investments. Investors (called limited partners or LPs) hire VCs (also called general partners or GPs) who have considerable expertise in assessing and overseeing entrepreneurial ideas.[1] Typically VCs have little capital of their own, so they are in essence money managers, helping investors supervise their investments. Because of standard incentive problems, VCs receive an interest in the firms they fund. They are unable to monetize their holdings and are instead forced to hold a substantial amount of their wealth in the form of these contingent stakes. Furthermore, significant time is required to oversee an investment, which means that a VC can manage only a few investments. Thus, VCs hold considerable idiosyncratic risk and must be compensated for bearing this risk.

The standard principal-agent problem ends here. If VCs were simply compensated by the principal for the services they provide and the risk they bear, then fund returns net of VC fees, earned by well-diversified investors, would be uncorrelated with idiosyncratic risk. Investors would compete away excess returns, resulting in zero net alphas.

In this paper, we go one step further, studying the impact of the investor-VC problem on negotiations between the VC and the entrepreneur. The sequencing is key. VCs and investors strike their bargain first, so the contract is set before the VC actually locates any projects. Thus, the investor-VC contract compensates the VC for the expected risk in the portfolio and not the realized risk.

The VC, with contract in hand, now negotiates with an entrepreneur. He does not care about the average risk but cares only about the risk in the project being considered. All else

[1] VCs are thought to have a number of skills relating to the funding and nurturing of new companies. For example, see Hellmann and Puri (2002), Hsu (2004), Kaplan et al. (2009), Sorensen (2007), and Ewens and Rhodes-Kropf (2012).

equal, if this project has greater than average risk, then the VC requires a larger return to invest. The contract with the investor is set, so the VC requires the entrepreneur to provide a price reduction on the deal that justifies his *personal* level of risk. However, the price reduction also benefits the outside investors. This "externality" requires the entrepreneur to give up more than the amount necessary to just compensate the VC. As a result, higher than average risk projects earn investors higher returns and lower than average risk projects earn investors lower returns, even though in expectation investors earn zero alphas.

If our model is correct, then fund returns net of fees could have zero alphas but should still be correlated with ex post total risk. We show formally that this result would not arise if there were no principal-agent problem. Even if, say, VCs must work harder to oversee higher risk firms (and demand higher fees), without a principal-agent problem investors' net returns would not depend on risk. Therefore, this surprising prediction be only be tested with VC investment fund returns *net* of fees, and this key prediction distinguishes our model from others.

We use newly available data on VC and buyout fund returns to test our model. Although our theory focuses on venture capital, we examine both VC and buyout data because our theory should apply to any market in which agents hold idiosyncratic risk and thus should also impact all private equity returns. We combine fund performance data—cash flows and net asset values—from Venture Economics, LP Source, and Preqin. Our data cover a significant fraction of the U.S. venture capital and buyout fund universe from 1980 to 2007. In our sample the average buyout fund has a value-weighted IRR of 14% and a beta of 0.72 and an alpha of 4%, and the average venture capital fund has a value-weighted IRR of 15% and a beta of 1.24 and a zero alpha.

We use this data to provide evidence that idiosyncratic risk is priced, even in net fund returns. We measure idiosyncratic risk and find that funds with higher realized risk have higher average *net* returns, exactly as predicted by the model. The results are robust to a series of robustness checks that address cross-sectional differences in funds, such as vintage year and investment stage. We find support for the theory because higher idiosyncratic risk funds tend to produce higher returns.

1. The Principal-Agent Problem

The trade-off between risk and incentives is a classic issue between a principal and an agent. Because the principal does not have perfect information about the agent's types and/or complete information about the agent's actions, the principal-agent contract must leave the risk-averse agent with too much risk relative to the first-best solution. The standard problem is that an agent could be a bad type or that an agent must take an action that is costly and unverifiable, such as expending effort. To combat either problem, the principal commits to a contract in which the agent's payoff depends on an observable output.[2] If output is subject to shocks that are beyond the agent's control, then these contingent contracts impose risk onto the agent.

In our model, the venture capitalist is an agent who must be compensated for the opportunity cost of his time. Because of the investor's (principal's) lack of information about the type of the VC or the VC's actions, the VC's compensation must depend on the returns of his chosen projects. This matches reality, as the standard compensation scheme in private equity and VC is a fixed payment (typically near 2% of the fund per year) and a fraction of the return above some benchmark (typically 20% of all positive returns). Because the VC has limited wealth, a significant portion of his wealth is the present value of his portion of the project returns.[3] The VC must invest significant time and effort (including board meetings, meeting with management/customers/suppliers, understanding the market, etc.) to help a project realize its value. Therefore, a VC can only manage a limited number of investments. Gompers and Lerner (1999) note that funds typically invest in at most two dozen firms over about three years. In addition, a VC's expertise may be limited to a particular sector or industry, which means that the VC may remain exposed to sector risk no matter how many projects he selects. Even if a VC can diversify across the entire VC industry, he may not be fully diversified because all VC projects may contain a correlated idiosyncratic risk component. For these reasons, the VC is exposed to significant idiosyncratic risk.

[2] Holmstrom and Ricart i Costa (1986) offer the idea that even if contracts do not explicitly depend on output, principals use the outcome of the agent's decision as a signal of the agent's quality. Because principals promote the high-quality agents (they cannot commit to provide full insurance), agents hold risk and their incentives are distorted.

[3] In practice, when VCs have significant wealth, they are typically required to invest a large fraction of it (perhaps 30–70%) in the fund to show that they "believe" in what they are doing. In other words they must invest in the fund either as a costly signal that they are good or to ensure greater effort.

Why not just combine a large number of VC investments into one much larger fund and compensate the VC based on total fund performance? The answer is that this would eliminate the link between a venture capitalist's compensation and his chosen projects. If the principal-agent problem were due to costly effort, VCs would exert too little of it. Said another way, the principal-agent problem remains regardless of how VC investments are aggregated into funds, so removing risk from the VC is not optimal. Furthermore, with aggregation VCs may still hold idiosyncratic risk because even in a larger fund the individual VC's career would depend on the projects he chooses rather than the overall portfolio.[4]

Our theory says that prices should be low in VC and private equity even if there is intense competition among VCs for projects. Prices are bid up until the VC is just indifferent, but this price is still below the price implied by, say, the CAPM. Because the VC needs to be compensated, gross expected returns on the venture capital investment are higher than the factor risks would suggest.

Because VCs correctly use a higher discount rate to evaluate projects, some projects are not taken that are positive NPV based on factor risk alone. This is in line with earlier work, as the principal-agent problem has consistently been shown to distort investment. Holmstrom and Ricart i Costa (1986) and Harris et al. (1982) show that principal-agent problems lead to underinvestment by the principal, whereas Holmstrom and Weiss (1985) show the friction leads to distorted investment choices. However, none of these papers explicitly consider prices. Our model of the pricing of idiosyncratic risk allows us to empirically examine the effect of the principal-agent problem on asset prices.

If the principal-agent problem truly has economic significance, it is here in the private equity market that we should see its impact. The prediction from our model is not easily explained by other potential theories, and its presence in the data gives us some confidence that the principal-agent problem does indeed affect prices and returns.

[4]Furthermore, the VC's ability to raise future funds depends on the success of his first fund (see Kaplan and Schoar (2005) and Gompers (1996)). Chevalier and Ellison (1997) also look at the same issue in mutual funds. Therefore, the VC's future income stream depends on the success of the fund. This compounds the effect of any idiosyncratic risk held by the VC. This idea is similar to Holmstrom and Weiss (1985), who focus on future career concerns rather than specifically contingent contracts.

2. The Model

The model has three participants: investors, venture capitalists, and entrepreneurs. Investors are willing to invest a total of I dollars into a fund that invests in N projects. Each project receives I/N dollars. Entrepreneurs have project ideas but need some help and guidance to realize the value of their ideas. Their ideas produce random output of $(1 + R_i)I/N$ if they are overseen by a skilled, involved investor and zero if they are not. Even with guidance, the projects have both systematic and idiosyncratic risk and an uncertain return $R_i = \alpha_i + \beta_i R_m + \varepsilon_i$, where R_m is the return on the market and ε_i is idiosyncratic risk. There is also a risk-free asset with zero return, and the single-period CAPM holds for all traded assets. The projects may be positive or negative NPV, $\alpha_i \gtreqless 0$. R_i and R_m are jointly normal, with $E[\varepsilon_i] = 0$, $E[\varepsilon_i R_m] = 0$, and $E[\varepsilon_i \varepsilon_j] = 0$, for all project pairs i and j.[5] Therefore, the expected return on a project is $\mu_i = 1 + \alpha_i + \beta_i E[R_m]$ with variance $\sigma_i^2 = \beta_i^2 \sigma_m^2 + \sigma_{\varepsilon_i}^2$. We let the subscripts i and j represent particular projects from the space of all possible projects, Ω.

For simplicity, we assume entrepreneurs and VCs have no personal wealth. Investors have money but do not have the skill to determine whether a project is positive or negative NPV or to manage a project. VCs have the ability to locate and successfully manage projects and determine the characteristics of those projects, α_i, β_i, and σ_{ε_i} (the investor knows the distribution of these parameter values but cannot verify a particular project's characteristics). To successfully manage a project, a VC must exert effort with an opportunity cost of e_{vc}. The effort of the VC is unverifiable. Therefore, the VC must be compensated to manage investments for the investors, and this compensation must provide the VC with the incentive to provide effort.

Managing a project is a time-consuming process. Therefore, initially we assume the VC is unable to successfully manage more than N projects. However, in Section 4 we relax this assumption and examine the VC's incentives to choose more or fewer projects.[6]

[5] $E[\varepsilon_i \varepsilon_j] = 0$ is not required, but it simplifies the exposition of the results. The Appendix drops this assumption.

[6] The principal-agent problem that surrounds many aspects of project choice is an interesting problem studied by Dybvig et al. (2010), Kihlstrom (1988), Stoughton (1993), and Sung (1995). Here we only focus only on the choice of risk.

Investors, venture capitalists, and entrepreneurs are all risk averse and require compensation for the risk that they hold. However, investors have enough wealth outside the fund that they are well diversified and therefore only require returns for their undiversifiable or factor risk.

The timing of the model is a three-stage game. In the first stage, the investors and VC form a fund and agree on a contract to govern their relationship. In the second stage, the VC negotiates the payoff schedule that the entrepreneurs give up to gain I/N dollars from the fund. The investments also occur in the second stage. In the final stage, project values are realized and payoffs are distributed.

We assume competition among investors gives VCs all the bargaining power when negotiating with LPs. Similarly, the competition among VCs for the scarce positive NPV entrepreneurial projects gives all the bargaining power to the entrepreneur. The assumption that all rents accrue to the entrepreneur minimizes the chance of finding any positive alphas in equilibrium.

Because of the principal-agent problem between the investor and VC, the optimal contract between them depends on the realized value of the projects. Further, because of the need to share risk between the investor who can diversify and the entrepreneur who cannot, the optimal contract between the fund and the entrepreneur must depend on output.[7] The results of this paper hold as long as the contracts depend on the output of the projects. However, to achieve simple closed-form solutions, we assume that both contracts are equity contracts. The negotiations are first over ϕ, the fraction of the fund given to the VCs, and then over the fraction, θ_i, of the company I/N dollars will purchase.

Holmstrom and Milgrom (1987) show that a linear sharing rule is optimal when effort choice and output are continuous but monitoring by the principal is periodic. The idea is "that optimal rules in a rich environment must work well in a range of circumstances and therefore would not be complicated functions of the outcome" (Holmstrom and Milgrom (1987) p 325). Dybvig et al. (2010) show that an option-like contract may be optimal if the agent chooses both effort and a portfolio. Under different conditions different contracts are optimal. We do not want to

[7] An output-based contact between the fund and the entrepreneur could also be motivated by a principal-agent problem or a situation in which the VC has more information about the success of the project than the entrepreneur, etc.

focus on the actual effort choice (see Gompers and Lerner (1999), Gibbons and Murphy (1992), and Holmstrom and Milgrom (1987) for interesting work that focuses on the effort decision), and we are not interested in the trade-offs involved in a particular contract. , we simply wish to motivate the use of a sharing rule rather than fixed compensation. In our work we take the form of the contract as given and focus on its implications for asset prices; the implications are the same as long as the contracts depend on the output.

2.1 Benchmark: No venture capitalist needed

To provide a benchmark to compare to the more interesting results to follow, we first consider the pricing when the investors can profitably invest directly in the entrepreneurial projects and projects require no oversight. To do so, we remove the VC from the problem but assume that the project is still positive NPV (specifically, we assume the investors can determine and expect to earn the α_i, β_i, and σ_{ε_i} of project i).

Given this setup, mean-variance preferences plus perfect competition among investors ensures that investors are willing to fund the project as long as $\alpha_i \geq 0$. That is, investors are willing to fund positive NPV projects, where discount rates are determined using the CAPM. Perfect competition among well-diversified outside investors implies that the entrepreneur retains all the economic rents from the project.

In the absence of a VC, investors fund a project directly. To begin we assume for simplicity that $N = 1$ (the appendix considers multiple projects). Investors put up I dollars and receive a fraction θ_i of the firm. The firm's random payoff is $(1 + R_i)I$ and investors receive $\theta_i(1 + R_i)I$, which implies that the beta of the investors' returns with respect to the market return is equal to $\theta_i\beta_i$.[8] Given this setup, the entrepreneur minimizes θ_i subject to giving the investors a fair return:

$$\min \theta_i, \quad s.t. \frac{\theta_i(1 + \alpha_i + \beta_i E[R_m])I}{1 + \theta_i\beta_i E[R_m]} = I, \quad 0 \leq \theta_i \leq 1. \tag{1}$$

[8] Although the concept of beta is scale independent, a change in θ changes the fraction of the project owned by the investor even though he invests the same amount. Thus, his exposure to the risk of the project changes with the fraction he owns. For example, suppose the investor puts up all of the cash but only receives 75% of the project payoff. An additional 1% return on the project increases the investor's return by only 0.75%.

The constraint is the expected payoff to the investors discounted at the appropriate CAPM rate and generates an NPV of exactly zero.

There is only one θ_i that satisfies the constraint, and it is given by

$$\theta_i = (1 + \alpha_i)^{-1}, \tag{2}$$

provided that $\alpha_i \geq 0$. Because the fraction θ_i of the firm is worth I dollars, the so-called *postmoney* implied value of the whole firm is $I\theta_i^{-1}$ or simply $I(1 + \alpha_i)$, which reflects the investment plus the expected value added by taking on this positive NPV project. The so-called *premoney* value of the firm is just the postmoney value less the amount contributed by investors, or in this case $I\alpha_i$. This implies that all the rents accrue to the entrepreneur.[9]

2.2 The venture capitalist's impact on prices

Now we address the more interesting case in which there is a VC present. As before, the entrepreneur gives up a fraction of the firm θ_i to the investors, but now the investor gives the VC a fraction of the firm $\phi\theta_i$ and retains the fraction $(1 - \phi)\theta_i$.

The VC is risk averse with exponential utility over terminal wealth w:

$$u(w) = -\exp(-Aw), \tag{3}$$

where A is the VC's coefficient of absolute risk aversion. If terminal wealth is normally distributed, then maximizing expected utility is equivalent to

$$\max\ \mu_w - \frac{1}{2}A\sigma_w^2, \tag{4}$$

where μ_w and σ_w^2 are the mean and variance of wealth. This functional form for utility allows for a closed-form solution but does not drive the results. The appendix allows for a general risk-averse utility function.

[9] A simple example will help clarify the terms postmoney and premoney value. If the entrepreneur convinces the investor that his firm/idea is worth $2 million and the investor invests $1 million at that valuation, then the value of the firm premoney is $2 million and the postmoney value is $3 million. These terms are used to make it clear that although the investment increases the value of the firm, it does not change the price of the stock (there is more money but also more shares).

The VC has no other wealth but has outside opportunities that give him a certain payoff e_{vc}. To manage potential investments, the VC requires compensation that generates at least as much utility as e_{vc}, the opportunity cost of his effort.

We derive the solution using backward induction and begin with the second-stage negotiations. In the second stage the VC locates a suitable project, determines its characteristics, α_i, β_i and σ_{ε_i}, and negotiates with the entrepreneur. As in the benchmark case, the entrepreneur minimizes the fraction θ_i. However, this minimization is now subject to providing the VC with utility greater than the opportunity cost of his effort. Thus, the introduction of the VC alters the constraint faced by the entrepreneur from the benchmark case. Formally, the minimization problem is

$$\min\ \theta_i, \ \ s.t.\ \phi\theta_i I\mu_i - \frac{1}{2}AI^2\phi^2\theta_i^2\sigma_i^2 \geq e_{vc},$$

where ϕ is the predetermined contract between the VC and the investor, $\sigma_i^2 = \beta_i^2\sigma_m^2 + \sigma_{\varepsilon_i}^2$ is the total variance of payoffs, and $\mu_i = 1 + \alpha_i + \beta_i E[R_m]$ is the expected return on the project.[10]

The entrepreneur wants to minimize the VC's and investor's take subject to the VC's constraint, and because the market is competitive, the offered contract provides a certainty equivalent of exactly e_{vc}. The binding constraint is quadratic in ϕ and yields the following expression for the share of the company offered to the VC in equilibrium:

$$\theta_i^* = \frac{\mu_i - (\mu_i^2 - 2Ae_{vc}\sigma_i^2)^{\frac{1}{2}}}{A\phi I\sigma_i^2}. \tag{5}$$

Note that the model implicitly assumes that the VC has no access to the capital markets. If he could, the VC might want to hedge out his market risk by trading in the market portfolio. Based on our conversations with venture capitalists, we do not believe that such hedging is common, but if the VC were able to eliminate all market risk, pricing would still be affected by idiosyncratic risk rather than total project risk.

Moving back one stage, to the first stage of the model, the VC and the investors must negotiate the equity contract that will govern their relationship. At this stage the VC has

[10]We assume that for $\theta \in [0, 1]$ the VC's utility increases with θ. Specifically this requires $\phi I\mu_i - AI^2\phi^2\sigma_i^2 > 0$. This eliminates the economically unreasonable (but mathematically possible) outcome that the VC's utility is improved by decreasing the fraction of the firm he receives.

not yet located a suitable investment, so the characteristics of the investment are not known. However, both the VC and investors can determine the distribution of the subset of projects that the VC would accept in the second stage, $\Omega_{vc} \subset \Omega$. Therefore, before an investment has been located investors' expectations are over the subset of projects Ω_{vc}.[11]

In negotiating a contract, the VC attempts to maximize his expected utility subject to the investors receiving a fair return in expectation for the risk they hold:

$$\max_{\phi}\ E_{\Omega_{vc}}\left[u(w(\phi))\right], \quad s.t.\ E_{\Omega_{vc}}\left[\frac{\theta_i^*(1-\phi)\mu_i I}{1+\theta_i^*(1-\phi)\beta_i E[R_m]}\right] \geq I.$$

As in the benchmark case, the constraint binds because we have assumed perfect competition for VCs and investments. However, the constraint now includes an expectation because the investor does not know the project characteristics when he negotiates with the VC.

To get an easy-to-interpret closed-form solution, we make the following simplifying assumption. We assume that there are only two equally likely projects within Ω_{vc}, and each project only differs in its level of idiosyncratic risk $\sigma^2_{\varepsilon_i}$. Thus, the VC receives a different fraction θ_i^* from each project. These assumptions do not drive any of our results and are dropped in the general formulation in the Appendix; they simply make clear the effect of idiosyncratic risk. The binding constraint becomes,

$$\frac{\theta_1^*(1-\phi)\mu_1 I}{1+\theta_1^*(1-\phi)\beta_1 E[R_m]}\frac{1}{2} + \frac{\theta_2^*(1-\phi)\mu_2 I}{1+\theta_2^*(1-\phi)\beta_2 E[R_m]}\frac{1}{2} = I, \tag{6}$$

where $\mu_1 = \mu_2 \equiv \mu$ and $\beta_1 = \beta_2 \equiv \beta$. Solving for ϕ yields,

$$\phi^* = 1 - \frac{1}{\sqrt{(1+\alpha)\theta_1^*\theta_2^*\beta E[R_m] + \frac{1}{16}\left(\theta_1^*+\theta_2^*\right)^2\left(1+\alpha-\beta E[R_m]\right)^2} + \frac{1}{4}\left(\theta_1^*+\theta_2^*\right)\left(1+\alpha-\beta E[R_m]\right)}. \tag{7}$$

[11] The expected returns are not normally distributed because a mixture of normals is not normal. However, the investors are assumed to have mean-variance preferences and the VC's expected wealth is still normal conditional on a chosen project. Therefore, the investor is willing to accept a contract as long as the expected present value of his return is greater than his investment.

There is clearly a solution to Equations (5) and (7).[12] However, as developed below there is not necessarily a solution with θ^* and ϕ^* between zero and one—a deal may be economically impossible.[13]

2.2.1 What if there were no principal-agent problem?

A central insight of our model is that in pricing and in capital budgeting, the principal-agent problem introduces a wedge between gross returns on investment and net returns to investors. We will show that the size of this wedge varies with the level of idiosyncratic risk and affects expected returns to investors. However, even without a principal-agent problem, there would still be a wedge as long as there are VC fees paid out of the gross returns. Thus, it is important to distinguish which results are due simply to the wedge between gross and net returns and which results are due specifically to the principal-agent problem. To do this, we develop a parallel model without the principal-agent problem. The formal development of this model can be found in the Appendix, but we provide an overview here.

If there were no principal-agent problem, the VC would still locate projects and negotiate with the entrepreneur for a share of the project, but the investor would rely on the VC to take actions in the investor's best interest. VC compensation would not need to depend on fund performance. In this case, the VC's payment would depend on the project's expected returns (μ_i) rather than the realized returns. The VC's compensation must, of course, still be greater than or equal to the opportunity cost of his effort, e_{vc}, but the VC would hold no risk.

The effort required from the VC might also depend directly on the variance of the project. For example, if higher risk projects are more costly to evaluate or more costly to oversee, then

[12] Proof: $\phi^*(\theta_1^*, \theta_2^*)$ is monotone and for any $\theta_2^* : \phi^*(0, \theta_2^*) < \infty$ and $\lim_{\theta_1^* \to \infty} \phi^*(\theta_1^*, \theta_2^*) = 1$. The inversion of Equation (5) is monotone, and $\lim_{\theta_1^* \to 0} \phi^*(\theta_1^*) \to \infty$ and $\lim_{\theta_1^* \to \infty} \phi^*(\theta_1^*) = 0$. Therefore, single crossing is satisfied, and there must be an equilibrium for any θ_2^* (though not necessarily an economically reasonable one). We are only interested in the positive root since $\sqrt{\frac{1}{16}\left(\theta_1^* + \theta_2^*\right)^2 (1 + \alpha - \beta E[R_m])^2} = \frac{1}{4}\left(\theta_1^* + \theta_2^*\right)(1 + \alpha - \beta E[R_m])$ the negative root would yield $\phi > 1$, which would not make economic sense.

[13] Note that all VCs get the same contract because ϕ^* depends on the expected risk. Furthermore, in our model VCs generate better or worse ex post returns because they find projects with more or less risk and not due to skill differences. This predicts that the LP-VC contracts would be very similar across VCs and across time. Overall, the remarkable stability of the VC contract (2% management fee and 20% carried interest) is a puzzle. The role of idiosyncratic risk may help inform the debate; however, our model holds constant potentially important aspects of the venture environment, such as learning about VC quality. Recent work by Marquez et al. (2012) and Hochberg et al. (2012) provides insightful examinations of this puzzle.

the VC's effort can be written as $e_{vc}(\sigma_i^2)$, an increasing function of project variance. Note that even if VC effort depends on the risk, in the absence of the principal-agent problem, the principal can simply agree to a contract that pays the VC more if the required effort is more. In this case the VC still holds no risk but is compensated more for greater required effort.

Below we compare the implications from our model to a model without the principal-agent problem. Some results hold as long as there is a VC paid out of gross returns, and some are specific to the principal-agent problem. This will allow us to empirically distinguish the principal-agent problem from many other theories.

2.2.2 Theoretical implications In what follows, we present the main results in Theorems 1 through 4, and then in the corresponding corollaries we consider the alternative in which there is no principal-agent problem. The corollaries show that Theorems 1 through 3, although interesting, cannot help us empirically distinguish our model. Theorem 4 is the key implication of our model and the theorem we test. All proofs are in the Appendix.

Theorem 1. Venture capital gross investment returns have positive gross alphas. Investor returns net of fees have zero alphas on average.

It appears that the investment has expected returns that are too high. On average, this is not so. Nobody expects excess returns in this model. The returns above the benchmark case are just enough in expectation to compensate the VC for his services and for the idiosyncratic risk he holds. This is consistent with Cochrane (2005), who finds that individual VC investments earn positive alphas at the project level.

It is interesting to note that relative to the benchmark case with no VC needed, the entrepreneur must give away too much of the firm in return for the investment. Here, it is the entrepreneur who must compensate the VC for the additional risk that the investor requires the VC to hold even though the entrepreneur has all of the market power in the model. This is because the investor must on average earn a return commensurate with the factor risks or he will not participate in the VC market. In equilibrium all investment expenses must be borne by the entrepreneur.

Theorem 1 is an implication of the principal-agent problem. However, this result is not too surprising and cannot help us empirically distinguish our model. As the following corollary shows, Theorem 1 holds in a model without the principal-agent problem.

Corollary 1. Even if there is no principal-agent problem gross investment alphas may still be positive.

Our theory predicts positive alphas before fees. However, as long as VC fees are nonzero, alphas before fees should be positive. Thus, we cannot use Theorem 1 to test our theory. For example, Cochrane's (2005) empirical finding of large alphas on VC projects does not provide any evidence of a principal-agent problem. We need more.

Theorem 2. Given any positive NPV project, if the total risk is large enough, then the VC does not invest. Furthermore, if the ex ante expected α of the universe of projects that the VC would accept is positive but sufficiently small, then the investor does not invest.

Conditional on a contract with the investors, the VC would not be willing to accept some positive NPV projects that have high risk. Furthermore, although (for a given ϕ) the VC would be willing to accept some negative NPV projects[14] with low risk, the set Ω_{vc} must include projects with high enough α or the investor would be unwilling to provide the VC with a contract at all. In equilibrium, a draw from the set Ω_{vc} (the only investments that will occur) must have a high expected α relative to its total risk.

When a paper claims that the NPV rule is no longer valid, it is important to ask which NPV rule is being referenced and whether a suitably adjusted NPV calculation might restore order. In this context, it is useful to think of the VC's share of the firm as consisting of two parts. One part is compensation to the VC for his effort, and the other part is compensation to the VC for the risk that he must hold. The value of the VC's effort could and, perhaps, should just be taken out of the net cash flows. This would go part of the way toward restoring

[14]For the VC to choose to invest, the VC's constraint must be satisfied. Given ϕ^*, the constraint, $\phi^*\theta_i I\mu_i - \frac{1}{2}AI^2\phi^{*2}\theta_i^2\sigma_i^2 \geq e_{vc}$, can be satisfied if the venture capitalist has sufficiently low risk aversion (small A) but $\phi^*\theta_i I\mu_i \geq e_{vc}$. Because the entrepreneur increases θ_i until the constraint is satisfied, and the largest $\theta_i = 1$, the constraint reduces to $\phi^* I\mu_i \geq e_{vc}$ or $1 + \alpha_i + \beta_i E[R_m] \geq e_{vc}/\phi^* I$. Therefore, a VC with sufficiently low risk aversion accepts a negative NPV project as long as the total return is large enough.

the NPV rule. Compensation to the VC for risk is not quite the same, however, because riskier projects require the VC to bear more risk and imply a higher hurdle rate.

Theorem 2, although interesting, has the same problem as Theorem 1. The following corollary shows that the same result would hold for a model without the principal-agent problem.

Corollary 2. Even if there is no principal-agent problem some positive NPV projects may not get done.

Because VCs use a higher discount rate to evaluate projects, some projects that are positive NPV are not done based on factor risk alone. However, it is also the case that compensation that does not depend on fund returns has the same qualitative effect. Therefore, as with Theorem 1, Theorem 2 cannot help us empirically determine if our theory is correct.

Theorem 3. All else equal, the price the entrepreneur receives is decreasing in the amount of idiosyncratic risk. Therefore, gross returns are positively correlated with ex post idiosyncratic risk.

If unavoidable principal-agent problems make diversification impossible, then idiosyncratic risk must be priced. Therefore, VC gross returns should be correlated with total risk, not just systematic risk. Projects with higher total risk should have higher returns.

It might seem that this theorem could help us empirically distinguish our model, because idiosyncratic risk is related to returns. However, the following corollary also shows that this prediction could also arise from other simple models.

Corollary 3. Even if there is no principal-agent problem, the price the entrepreneur receives still may be decreasing in the amount of idiosyncratic risk.

For example, if higher risk projects are more costly to evaluate or more costly to oversee, then even if there is no principal-agent problem the entrepreneur must pay more to get people to invest. So gross returns would be higher for high-risk projects. Therefore, Theorem 3 cannot help us distinguish the effect of the principal-agent problem from other models. To do this, we must look at *net* returns.

Once we remove the VC's fees, then seemingly the net return to investors should be unaffected by idiosyncratic risk, particularly because investors are perfectly competitive. However, the following theorem shows that the return to investors *is* affected by idiosyncratic risk.

Theorem 4. On average, venture capital investment returns net of fees increase with the amount of ex post idiosyncratic risk, even though investors are well diversified and face competitive market conditions.

Proof. Assuming an economically reasonable equilibrium exists, the net fraction owned by the investors equals $\theta_i - \theta_i \phi^*$. Theorem 3 showed that the fraction given up by the entrepreneur, θ_i, varies with idiosyncratic risk, $d\theta_i / d\sigma^2_{\varepsilon_i} > 0$. However, the share taken by the VC, ϕ^*, does not change with the realization of $\sigma^2_{\varepsilon_i}$ because it is determined ex ante before the project risk is known. Therefore, the fraction held by investors is a function of $\sigma^2_{\varepsilon_i}$, and net returns will be correlated with realized idiosyncratic risk. Competitive conditions ensure that the expected alpha is zero, but realized alpha is positive on average for high idiosyncratic risk projects and negative for low idiosyncratic risk projects. □

This is the most important and most surprising theorem in the paper. We later test this theorem and demonstrate that even though investors earn zero alphas in expectation, net returns are still correlated with ex post idiosyncratic risk.

This key prediction follows directly from the principal-agent problem. It is surprising on first blush because one would expect the principal-agent problem to have no effect on returns of well-diversified investors. However, when we consider that the principal-agent problem arises because the investor cannot monitor the VC and must therefore negotiate a contract in advance, we begin to see how the principal-agent problem could affect investor returns. The contract is designed to compensate the VC for the expected risk of the portfolio, but because the VCs invest in so few projects, realizations of high- and low-risk portfolios should happen with some frequency. What happens if the VC locates a surprising number of high-risk projects? He negotiates better terms from the entrepreneurs. The externality in this negotiation is that the investor also benefits from the VCs negotiation. This is not internalized by the investor-VC team because their contract is already set. Thus, to receive an investment from the VC, the entrepreneur sets a lower price and the investor benefits.

This is the key prediction of our model because it is not easily generated without the principal-agent problem. If, for example, high-risk investments had higher costs of investing, or monitoring high-risk investments was more costly, then high-risk projects would have higher gross returns, *but this would not show up in investors' returns.* The following corollary makes it clear that these results only occur when there is a principal-agent problem.

Corollary 4. Without a principal-agent problem, even when the VC's compensation depends on idiosyncratic risk, the net returns are independent of the idiosyncratic risk.

Without the principal-agent problem, any excess return required to compensate the VC goes to the VC. Therefore, the investors' return net of fees just compensates them for their beta risk. Theorem 4 allows us to distinguish between a positive alpha that is simply the result of an uncompetitive market or simply because VC's require compensation, and a positive alpha that is due to the pricing of idiosyncratic risk. If the principal-agent problem is of true significance in the VC arena, then the investors' returns should be correlated with risk even though the investors earn no excess returns on average.

3. Empirical Tests

3.1 Data

We use vintage year performance data from three commercial data providers: Venture Economics (VE), LP Source, and Preqin. The data cover performance—cash flows and net asset values—for buyouts and venture capital funds from 1980 to the end of 2011. Stucke et al. (2011) detail the methodology and coverage of Venture Economics and Preqin. LP Source is a dataset of fund performance sourced with public information (similar to Preqin) maintained by Dow Jones. For our analysis, we aim to use the maximum and best information available from all data sources. The Venture Economics data covers fund performance from 1980 – 2002. Stucke (2011) shows that the Venture Economics data stop accurately updating in 2001, so we only use pre-2000 cash flows. We supplement these data with fund returns from Preqin and LP Source.

Using the firm and fund names, we find duplicate funds in Preqin and LP Source. For duplicate funds, we use the Preqin data because they have more detailed and longer time series of fund cash flows than LP Source.[15] Next, using fund size, vintage year, and type (buyout or VC), we search for duplicates with Venture Economics.[16] For any duplicates, we use the Venture Economics data. This leaves us with a merger of three sets of data. This merged database combines Venture Economics for funds between 1980 and 1997 and the merged dataset of Preqin/LP Source for vintage years through 2007. The total number of unique funds by vintage year and type is shown in Figure 1. The coverage by data source is in Figure 2.

The final dataset of interest includes all buyout and VC funds with at least 16 quarters of returns with a vintage year between 1980 and 2007 (returns through 2011).[17] We are left with 741 buyout and 1,040 VC funds.

Although the theory above was developed with venture capital in mind, it applies to any situation with a three-way principal-agent interaction. This interaction occurs in private equity more generally because partners in buyout firms are also exposed to significant idiosyncratic risk. However, one might expect the results to be less pronounced when investing in areas with less idiosyncratic risk. Furthermore, buyout firms are often competing against strategic firms to buy target companies. Our theory suggests that private equity buyers must earn a larger return than strategic acquirers. This should make buyout firms less competitive and only able to win if they can improve the target firm enough to provide the larger needed return. Buyout firms should not be competitive for all targets, but when they win, the return should still be related to the idiosyncratic risk of the target.

Table 1 summarizes the characteristics of the funds in the sample. Venture capital funds are generally older (1992 average vintage year) compared with buyout funds (average 1996).

[15] LP Source cash flow data start in 2002, although many funds have earlier vintages.

[16] We lack significant identifiers of funds in Venture Economics, so we use these observables to search for duplicates.

[17] The dataset is cleaned by removing obvious data errors and ignoring funds whose values go to zero and back to positive. LP Source had instances of the same fund because multiple LPs were investors. We kept one observation per fund, keeping the fund/LP with the most information.

This difference stems from slow growth of new venture funds in the post-2001 era and the large increase in buyouts formed prior to the financial crisis of 2008. Venture capital funds can invest across a range of industries and stages. We have information on the latter, which shows that about 39% make early-stage investments. The table presents the fraction of the full sample sourced by each data provider.

Table 1 also reports the average and size-weighted IRRs for both fund types, calculated using the full set of cash flows to liquidation or the end of sample. The average VC fund in the sample has an IRR of 13% and when size-weighted, increases to 15%. These compare with across-database averages of 15% and 17%, respectively, in Harris et al. (2012) and 11% in Robinson and Sensoy (2011). Buyout fund IRRs of 13.8% and 14% mostly match the numbers reported in Harris et al. (2012). Both sets of fund returns exhibit significant volatility: 30% and 44% annualized for VC and buyouts.

3.2 Estimating risk and return

Our main empirical prediction is that average returns are increasing in the amount of idiosyncratic risk. Ultimately, we calculate the root-mean-squared error (RMSE) from the three-factor returns model for each fund and form portfolios based on this estimate to test for correlation with returns. Unique features of the data and private equity market limit the use of standard factor models and idiosyncratic risk estimates.

For publicly traded stocks with a complete price history, it is straightforward to estimate both factor loadings and idiosyncratic risk. In a single factor model, for example, idiosyncratic risk is the standard deviation of the residual in the market model regression:

$$r_{it} = \alpha_i + \beta_i r_{mt} + \varepsilon_{it}, \tag{8}$$

where r_{it} and r_{mt} are the excess returns over the risk-free rate. This equation can be estimated consistently using a time series of returns. In the present case, funds themselves report the value of their investments each quarter. If these estimates of value simply have i.i.d. measurement errors, then these errors bias upward the estimates of idiosyncratic risk. The measured residuals also would be negatively autocorrelated, though that is not particularly relevant here. The situation is analogous to bid-ask bounce, and the volatility effects of that particular measurement error are addressed by Roll (1984).

Measurement error is not a problem if these measurement errors are uncorrelated with returns or the true amount of idiosyncratic risk, because we do not care much about the actual level of idiosyncratic risk. As long as measured idiosyncratic risk remains informative about the true amount of idiosyncratic risk, then we can test the theory by testing for a positive association between measured idiosyncratic risk and returns.

A bigger problem is that funds tend to adjust their net asset values slowly. In fact, the National Venture Capital Association provides mark-to-market guidelines that explicitly encourage such conservatism. For example, according to the guidelines, a startup's value should be only written up if there is a subsequent financing round involving a third party at a higher valuation. This impacts our estimate of fund quarterly return, which uses changes in reported net asset value (NAV), distributions (D_{it}), and takedowns (T_{it}). These quarterly returns are calculated as $(NAV_{it+1} + D_{it+1} - T_{it+1} - NAV_{it})/(NAV_{it})$, or the percentage change in asset value after accounting for net cash flows from the limited partner.

If a fund adjusts its net asset value in a consistent, time-stationary way with a one-period lag, and the measured market return itself has no such lags, then the problem is identical to the nonsynchronous trading problem studied by Lo and MacKinlay (1990) and Boudoukh et al. (1994), among others. Systematic risk can be measured by projecting on current and lagged market returns and then summing up the estimated slope coefficients to obtain an estimator for beta (see Dimson (1979)):

$$r_{it} = \alpha_i + \beta_{0i} r_{mt} + \beta_{1i} r_{m,t-1} + \ldots + \beta_{4i} r_{m,t-4} + \varepsilon_{it}, \tag{9}$$

where r_{it} is the quarterly excess fund return calculated using cash flows and net asset values.[18]

[18]Figure 1 shows there is significant variation in the number of funds available each year. These differences imply that aggregated portfolio returns will be noisier in particular periods. To adjust for this heteroscedasticity, all the time-series regressions in the paper are weighted by the number of reported funds in a quarter.

The variance of the residual in this regression is a monotonic function of the true (unobserved) idiosyncratic risk. More lags can be added to this regression if the fund adjusts its returns with a longer lag.

The lagged factor method is also robust to various other simple measurement errors. For example, if all marks were biased upward by a certain fixed amount, all alphas would be biased upward, but this would not affect estimates of factor loadings or any of the cross-sectional relationships that we identify. Similarly, if individual fund marks are noisy, these should wash out in aggregating over many funds to form value-weighted portfolio returns. Finally, no matter how much the NAVs bias the quarterly returns, average NAV returns must eventually converge to cash flow IRRs over the life of the fund.

3.3 Market model estimates

The first estimation of risk and return starts with Equation (9). All funds in an asset class are aggregated into a single NAV-weighted portfolio, and its quarterly excess returns r_{it} are projected on contemporaneous and lagged market returns, r_{mt}, measured using the CRSP value-weighted index of all NYSE, AMEX, and NASDAQ stocks. The estimates in Table 2 demonstrate that funds mark to market with a substantial lag. Betas in this time-series regression are generally strongly positive out to lag 4.[19]

Summing up the current and lagged betas, the portfolio of VC funds has an estimated "long-run" beta of 1.24. Buyout funds have much lower estimated betas, with betas that sum to 0.72. In the private equity industry and in some academic papers, such as Kaplan and Schoar (2005), a common performance measure is the public market equivalent, or PME, which is equivalent to assuming that all private equity and venture capital investments have a CAPM beta of one. Our estimates suggest this may be a useful approximation. However, the betas in Table 2 for buyout funds are lower than our priors and our VC beta is lower than those of some other work. Korteweg and Sorensen (2010) report betas of 0.74 for seed investments, 2.7 for early-stage investments, and 2.6 for late-stage investments, and Driessen et al. (2012) report

[19] We also estimated regressions with additional lags but found insignificant covariances beyond a year.

2.7 for venture funds from 1980–1993. Our PE beta estimate exceeds the estimate of 0.4 from Kaplan and Schoar (2005) and is somewhat less than the 1.3 estimate of Driessen et al. (2012).

Alternatively, we look at fund performance measured against the Fama and French (1993) three-factor model. We aggregate funds into a value-weighted portfolio and run time-series regressions of quarterly fund returns on current and lagged factor returns. Specifically, we estimate

$$r_{it} = \alpha_i + \sum_{k=0}^{4} \beta_{ik}^{RMRF} r_{t-k}^{RMRF} + \sum_{k=0}^{4} \beta_{ij}^{SMB} r_{t-k}^{SMB} + \sum_{k=0}^{4} \beta_{ik}^{HML} r_{t-k}^{HML} + \nu_{it}. \qquad (10)$$

Column (1) ("All") of Table 3 reports the loading and excess return estimates from the three-factor model using four lags of each. The remaining columns report estimates of the size-quartile regressions of the same model. Venture capital funds have strong negative loadings on the book-to-market factor, consistent with their investments in small, high-growth opportunities. Larger VC funds in the third and fourth size quartile have larger loadings on this factor. Interestingly, venture capital funds do not load on the small-firm factor. The VC portfolios have statistically insignificant alphas across all size quartiles. Buyout funds, in contrast, exhibit some positive excess returns and have insignificant loadings on the size and book-to-market loadings.

3.4 Idiosyncratic risk and returns

Given a market model, we have two approaches to testing whether average returns are related to idiosyncratic risk. The first is a time-series method, and the second is a cross-sectional estimator motivated by Fama and MacBeth (1973).

3.4.1 Time series and RMSE. The time-series method first sorts directly on idiosyncratic risk. That is, for each of the 741 buyout and 1,040 VC funds with a return history of at least 16 quarters, we estimate Equation (10). The square root of the mean squared residuals is then a standard estimate of a fund's idiosyncratic risk. Funds are then sorted into quartiles based on their idiosyncratic risk, and value-weighted portfolios are formed. These returns are again estimated using (10), where our objects of interest are the estimates of α_i for the four quartiles. In particular, we focus on the estimate of $\hat{\alpha_4} - \hat{\alpha_1}$ or the estimated difference in alphas between the two extreme quartiles. As before, this last time-series regression is weighted by the number of funds present in that quarter.[20]

The results are in Table 4. Consistent with the theory, portfolios with higher idiosyncratic risk exhibit higher returns. For VC funds, the lowest quartile has an alpha of -1.6% versus 2.55% for the highest quartile. The latter is statistically larger than the former. Although the estimates are not as stark, the same one-sided test for the buyout sample difference is 1.47% and has a p-value of less than 10%.

Although these results are consistent with the theory introduced here, there are other possible explanations for these results. For example, our tests hinge on the validity of the assumed linear factor model. If the linear factor model is wrong, then residual risk is correlated with expected returns, because at least some of the relevant covariance is not captured by the factor or factors and is instead lumped into the residual with the true, unpriced idiosyncratic risk.

To investigate this, we also redo the empirical tests using alternative factors. The results are nearly identical if we instead use just NASDAQ stocks to construct the market return, and the results are unchanged if we use a single market factor rather than the three Fama-French factors. We also check for parameter stationarity throughout the sample. When we split the sample, we find no evidence that the linear factor model differs across the two halves. Finally, we address concerns that many of the funds in the the data are younger and cut the sample at the 2002 vintage. Table 5 repeats the exercise above, and we find that the fourth quartile alpha (Column 4) is still statistically larger than the first quartile (Column 1).

We have shown that portfolios sorted by fund-level RMSEs from a three-factor regression have a strong pattern of excess returns. It is possible that such a correlation is driven by other characteristics of funds within the RMSE quartiles. Table 6 is a first attempt at addressing

[20]Because we can measure idiosyncratic risk, it might seem investors and VCs should contract on it. However, our estimates are measured with error (which is why we form portfolios). VCs paid based on measured idiosyncratic risk would still hold considerable idiosyncratic risk, and this would not solve the problem. Furthermore, this would give VCs the incentive to manipulate idiosyncratic risk or its measurement, thereby reducing any value from contracting on it. In any case, investors have little to gain by contracting on idiosyncratic risk, as they are already expecting zero alpha.

whether the RMSE portfolios are capturing other observable feature of funds. The merged data have several characteristics of VC funds and a few features of buyouts available. We observe the fund vintage, the sequence number, the investment type by stage (for VC), and the total capital inflows into each market by vintage year (e.g., see Gompers and Lerner (2000) for VC). The averages by quartile show that fund vintage, fund size, and total capital inflows strongly correlate with RMSE. These relationships motivate a cross-sectional analysis of idiosyncratic risk and returns.

3.4.2 Cross-section and RMSE. We take two approaches to controlling for cross-sectional differences in funds and RMSEs. The first follows Ang et al. (2006) with a refinement of our time-series estimator. In that paper, the authors study the pricing of aggregate volatility in the cross-section of returns. They find that the the extreme quintile of portfolios sorted by idiosyncratic volatility have statistically different alphas; however, the characteristics of stocks in these buckets differ. For example, in their sample of publicly traded firms, only 1.9% of the value of stocks are covered in the top quintile of volatility.

For each RMSE quartile and fund type, we first sort by the observable fund feature, such as size. Then within each quartile, we sort again by the RMSE. Thus, within each size or other observable quartile, quartile 4 has the funds with the highest idiosyncratic volatility. Table 7 shows that within each size quartile, the portfolio with the highest RMSE also has the largest alpha estimate. The Column "4-1" takes the difference in alpha estimates between the two extreme quartiles and reports the one-sided test p-value.[21] These double sorts quarter the sample for each α estimate, so we expect significance to fall. All differences are positive, with only quartile 2 of VC funds having a statistically insignificant value. The average of the alphas within the RMSE quartile and across the fund observable allows us to control for size, sequence, or other characteristics. The difference of 3.59% for fund size shows that the RMSE relationship with returns cannot be fully explained as a size effect. The second part of each Panel in Table 7 presents these cross-section estimates for other observables.

[21] Although we often lose statistical significance for the top alphas of the high RMSE quartile in Table 7, the Column 4 alpha coefficient is always positive and economically larger in magnitude than the negative coefficient for the smallest RMSE (Column 1). Furthermore, the alpha increases from Column 1 to 4 in nearly all specifications. This monotonicity says that even if realized returns in VC have been a bit lower than expected, the higher RMSE group has consistently earned a higher return.

The row "Fund Sequence" creates buckets by the sequence of the firm's fund: 1, 2, 3, or 4 and greater than 4. Similarly, the "Vintage Year" sort breaks funds into five time periods, starting in 1980. "Total Inflows" uses the total capital invested into entrepreneurial firms or funds raised in LBOs in each vintage year, which then sorts funds into quartiles by this level. Finally, "Fund Investment Stage" buckets VC funds into early stage, late stage, and balanced. For each of these additional sorts, the difference in the estimated alphas between the two extreme quartiles of RMSE is statistically significant and positive. We conclude that size, fund sequence, vintage year, and capital inflows cannot explain the relationship between average returns and idiosyncratic volatility for VC funds. The smaller set of observables for buyout funds leads to the same conclusion.

This approach goes a long way toward addressing concerns about omitted variables; however, we cannot jointly control for factors through double sorts. Our final set of specifications uses the Fama and MacBeth (1973) methodology to test for cross-sectional explanations for the relationship between returns and idiosyncratic risk.[22] Consider the following specification of the cross-section of quarterly fund returns:

$$r_{it} = \alpha_t + \gamma X_{it} + \rho \sigma_i + v_{it}. \tag{11}$$

Here, r_{it} is the quarterly return for fund i in quarter t, X_{it} contains all the controls discussed above, and σ_i is the fund's estimated idiosyncratic volatility. Unlike the asset pricing analog to Equation (11), we are not interested in estimating risk premiums and cannot control for systematic risk estimates as they are too noisy. Instead, we use the Fama and MacBeth (1973) econometric technique of pooled cross-sections to address cross-sectional differences in fund returns. Equation (11) is estimated for each quarter from 1980 to 2011, and the coefficients α_t and γ are averaged to obtain the standard Fama-MacBeth estimates and heteroscedasticity-adjusted standard errors with a two-quarter Newey-West lag structure.[23]

Table 8 reports the results of these regressions for buyout and VC funds. The coefficients of interest are on the variables "Idiosyncratic volatility" and "RMSE quartile." The latter is

[22]The fund data and time series are too short to create a measure of idiosyncratic volatility as in Ferreira and Laux (2007), so we instead use the single measure for each fund.

[23]The results are robust to an alternative 4, 6, or 8 quarter lag structure for the error term.

defined as the RMSE quartile by vintage year. Columns (1) and (3) show a strong positive correlation between quarterly fund returns and idiosyncratic volatility levels. To capture any nonlinearity, we introduce controls for quartiles of RMSE. With the excluded category as the lowest quartile, the positive, significant, and monotonically increasing coefficients from the remaining quartiles are directly in line with the model predictions. We conclude that the patterns of excess returns and idiosyncratic volatility are not driven by size, fund sequence, vintage, or capital flows.

3.5 Stale NAVs and idiosyncratic risk

Another concern is a relationship between the stale NAVs of a VC fund and the measure of idiosyncratic risk. For example, a high-performing fund could mark its portfolio more often, resulting in greater measured idiosyncratic risk and also a large alpha, whereas poor performing funds could have more stale values and less measured idiosyncratic risk.[24] We address this concern in three ways. First, for each VC fund, we calculate the fraction of flat NAVs or zero quarterly returns. We find no significant correlation between this variable and a fund's total return. Next, Table 9 repeats the Fama-MacBeth regressions with an additional control for the fraction of stale values ("% flat NAV"). The inclusion of this variable has no impact on the conclusions. Finally, in an unreported table, we split the VC fund sample into two halves based on the fraction of observed zero quarterly returns for all funds with at least 16 quarters of returns. The patterns of positive alpha in the high quartile RMSE and negative alpha in the lowest quartile RMSE remain for both subsamples. We conclude that heterogeneity in NAV staleness cannot explain our results.

4. Extensions: The Risk of the Portfolio

All of the results in the paper so far hold with any form of contract between the investor and VC, as long as the compensation depends on the payoff of the portfolio. However, these results rely on the assumption that the VC cannot alter the risk of the portfolio. This section considers the validity of that assumption by allowing the VC to maximize his utility by altering portfolio

[24] It is possible that a fund with significantly more stale NAVs could have either a better or worse fit to the three-factor model and thus higher or lower idiosyncratic risk. Therefore, the issue must be examined empirically.

risk. We show that properly structured option contracts (similar to real VC compensation contracts) eliminate the VC's desire to alter the portfolio risk. This demonstrates that relaxing the assumption that the VC cannot alter the portfolio risk would not invalidate our results.

This section also explains why the standard VC contract pays the VC a fraction of all positive returns on the portfolio. This makes the VC's payoff similar to a call option. Because increasing volatility increases the expected payoff from the option, it might seem that this type of contract would encourage excessive risk taking by the VC. Such incentives could be removed by simply giving the VC an equity contract. So why does the standard contract contain an option? Furthermore, why is the return benchmark above which the VC shares in the profits, usually equal to zero?[25] It would seem that the VC should have to at least beat the risk-free rate (if not some higher benchmark) before sharing in the upside. This section shows that the answer to both questions is the same; the VC contract must neither encourage nor discourage the VC to spend time to alter the risk of the portfolio. The diversified investor does not care about the risk in any small part of his portfolio, so the investor wants the VC to increase the mean, not change the amount of idiosyncratic risk. We show that an equity contract encourages diversification, and an out-of-the-(expected)-money option contract encourages excessive risk taking. This demonstrates that an option with a low strike price (i.e., no hurdle rate) encourages effort, while providing little benefit to changes in risk.

To consider the question of risk, we examine a very general formulation of our model with $N > 1$ and continuous VC utility function over wealth, $u(w)$. We assume that the VC is risk averse but likes wealth so that $u'(w) > 0$ and $u''(w) < 0$ and that the portfolio is sufficiently good that more of the portfolio is better for the VC. Let R_p represent the return of the portfolio, μ_p represent the expected return, and σ_p^2 represent the portfolio variance. We assume that an agreement among the VC and investors exists and ask the following: Given the equilibrium contract, does the VC wish to alter the risk of his portfolio? If he does, then it is not an equilibrium. If he does not want to alter risk, then allowing the VC to change the risk would not change the results.

[25] See Fleischer, Victor, The Missing Preferred Return (February 22, 2005). UCLA School of Law, Law-Econ Research Paper No. 05-8.

We wish to consider the benefits and costs associated with a VC who has the ability to find one more project than the marginal VC (i.e., alter the risk on the margin). Given an equilibrium, we examine the VC's attempt to maximize utility.

$$\max_{\sigma_p^2} E[u(w) \mid \sigma_p^2] \tag{12}$$

First, consider the simple case of an equity contract between the VC and investor. It is straightforward to see that with an equity contract, if the VC can choose $N \epsilon [\underline{N}, \overline{N}]$, then the VC will choose $N = \overline{N}$, or if the VC can decrease σ_p^2, then he will do so, all else equal. This follows directly from the fact that the VC is risk averse. Therefore, if the VC takes on one more project than expected, then the VC's utility will improve because the variance of the portfolio decreases.

We now show that moving to an option-like contract reduces the incentive to take on too many projects by providing a benefit to volatility. We assume that the VC-investor agreement gives the VC a fixed payment y and shares in a portion of the returns above some fixed benchmark, R_b. ω is sometimes referred to as the VC's carried interest. Therefore, the VC's payoff is of the form[26]

$$\begin{aligned} X_{vc} &= y + \max[\omega I(R_p - R_b), 0] \; if \; R_b \geq 0, \qquad (13) \\ X_{vc} &= y + \omega I R_b + \max[\omega I(R_p - R_b), 0] \; if \; R_b < 0. \end{aligned}$$

Given this form for the payoff, we can show how the VC's incentives to change risk are affected by the choice of benchmark, R_b.

Theorem 5. If the VC receives a payoff of the form in Equation (13), then for an appropriately chosen benchmark, R_b, which is below the expected return of the portfolio, μ_p, the VC has no incentive to change N or σ_p^2.

[26]This equation differs from a standard option payoff because in theory we could require the VC to share in some of the negative returns.

As long as R_b is chosen appropriately, the VC has no incentive to alter the risk of the portfolio. This ensures that our results are robust to the relaxation of the assumption that the VC does not alter the number of projects or the risk of the portfolio.

It is interesting to note that the appropriate benchmark return, R_b, is not the expected return on the investments, R_p. Instead, the optimal benchmark makes the option in-the-money (in expectation) at inception. This provides the risk-averse VC with the least incentives to spend time altering the risk characteristics of his portfolio instead of focusing on returns. This is, of course, optimal for the well-diversified investor in the VC fund. Although most work on option-based compensation suggests that options cause managers to increase risk, Carpenter (2000) also shows that options may not always cause managers to increase risk. Here our point is to show that a properly structured in-the-money option eliminates the desire of the VC to increase or decrease risk, and thus our model results are robust.

The intuition comes from thinking about the contract in the following way. Lowering R_b below R_p makes the contract like equity with a put. Increasing variance increases the value of the put but decreases the value of the equity (to a risk-averse VC). At the appropriate strike price, these two effects offset, and the VC does not wish to alter risk. However, if R_b is too low, then the contract is too much like equity and the VC wishes to reduce risk. If R_b is set at R_p (or above), then the contract is just a call option and the VC wishes to increase risk. Thus, a properly set in-the-money option contract eliminates the VC's desire to alter the risk of the portfolio.

If the principal-agent problem and idiosyncratic risk are important in the VC industry, then an in-the-money option-like contract (i.e., no hurdle rate) is not odd at all. The appropriate option contract encourages the VC to focus on managing investments, not altering risk.

5. Conclusion

Unavoidable principal-agent problems in the private equity and venture capital markets combined with the need for investment oversight result in idiosyncratic risk that must be priced. This extension of the principal-agent theory results in investor returns that are correlated with total risk, not just systematic risk. The model leads us to expect higher alphas, even net of fees, for funds with higher total realized risk. The empirical results imply that funds in the top quartile or realized idiosyncratic volatility have a 4% larger abnormal return than funds in the bottom quartile.

Although this paper has broad implications for any situation in which agents interact with a third party, the venture arena is the perfect place to examine the model's impact. Investors hire venture capitalists who are given significant autonomy over investments and their pricing. Thus, the principal-agent problem is of first-order importance. Overall, we demonstrate that our extension of the principal-agent problem to pricing is a central issue in the venture market and has considerable economic importance.

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Appendix

A.1 The model without a principal-agent problem

To parallel the main model, we assume that the VC must still negotiate with the investor to get a fraction, ϕ, but now this is a fraction of what the investor *expects* to receive from the investment, $\theta_i I \mu_i$. This is possible because the investor and VC can write a contract on μ_i and can rely on the VC to take actions in the investor's best interest. The VC's compensation must, of course, still be greater than or equal to the opportunity cost of his effort, e_{vc}. However, the VC's effort may depend directly on the variance of the project. In this case, $e_{vc}(\sigma_i^2)$, with $e'_{vc}(\sigma_i^2) \geq 0$.[27] Note that even if VC effort depends on the risk, in the absence of the principal-agent problem, the principal can simply agree to a contract that pays the VC more if the required effort is more. Thus, the VC still holds no risk but will be compensated more if her required effort is more.

With this setup and no principal-agent problem, the constraint in the entrepreneur's problem, Equation (5), would be *s.t.* $\phi\theta_i I \mu_i \geq e_{vc}(\sigma_i^2)$. Therefore, the fraction offered becomes $\theta'_i = \frac{e_{vc}(\sigma_i^2)}{\mu_i \phi I}$, where the superscript $'$ delineates no principal-agent problem. The constraint in the investor's problem, Equation (7), no longer requires an expectation over the type of project located because without the principal-agent problem the contract can depend directly on the realized parameters, α_i, β_i, and σ_{ε_i}. Thus, the share received by the VC becomes

$$\phi' = 1 - \frac{1}{\theta'_i \left(\mu_i - \beta_i E[R_m]\right)}. \tag{A1}$$

Proof of Theorem 1. Assuming a deal is economically possible,[28] the investors' constraint in Equation (6) is binding, and on average the investors earn zero alphas net of fees. However, the present value of the gross returns is $E_{\Omega_{vc}}\left[\frac{\theta_i^* \mu_i I}{1+\theta_i^* \beta_i E[R_m]}\right]$, which is greater than I because $(1-\phi) < 1$. Therefore, the gross returns are positive NPV.

Proof of Corollary 1. Without the principal-agent problem the constraint in the entrepreneur's problem, Equation (5), would be *s.t.* $\theta_i \phi I \mu_i \geq e_{vc}(\sigma_i^2)$. Therefore, the fraction offered to the VC becomes $\theta'_i = \frac{e_{vc}(\sigma_i^2)}{\mu_i \phi I}$. The constraint in the investor's problem, Equation (7), is unchanged. We assume a deal is economically possible.[29] Because $(1-\phi') < 1$ Theorem 1 ensures that alphas are still positive.

[27] If $e'_{vc}(\sigma_i^2) = 0$ for all σ_i^2, then we are back in the world in which the VC's effort does not depend on the level of risk.

[28] Equations (5) and (7) must cross at a point at which θ^* and ϕ^* are between zero and one, which always occurs for appropriately chosen parameters.

[29] Without the principal-agent problem an economically possible solution requires Equations (7) and $\theta'_i(\phi) = \frac{e_{vc}(\sigma_i^2)}{\mu_i \phi I}$ to cross at a point at which θ' and ϕ' are between zero and one. This always occurs for appropriately chosen parameters.

Proof of Theorem 2. Part 1: Given a function ϕ^* (based on projects the VC will accept, Ω_{vc}) negotiated among the VC and investors, for the VC to accept a particular project, the utility from accepting must exceed the opportunity cost of the time he must spend on the project. The resulting fraction of the firm that the entrepreneur must yield equals Equation (5). This share exceeds one if

$$\sigma_i^2 > \frac{2\mu_i \phi^* I - 2e_{vc}}{A\phi^{*2} I^2}, \tag{A2}$$

which is possible even if α (inside μ_i) is positive. Therefore, the VC would not accept projects with large total risk even if they were NPV positive. Note also that if $\mu_i I < e_{vc}$, then the project does not produce enough to compensate the VC for his time regardless of the variance.

Part 2:

If there are two possible projects in Ω_{vc}, then for small enough α

$$1 \geq \sqrt{(1+\alpha)\theta_1^*\theta_2^*\beta E[R_m] + \frac{1}{16}\left(\theta_1^* + \theta_2^*\right)^2 (1+\alpha - \beta E[R_m])^2} + \frac{1}{4}\left(\theta_1^* + \theta_2^*\right)(1+\alpha - \beta E[R_m]). \tag{A3}$$

Therefore, for small enough α, the ϕ negotiated among the investors and VC must be less than or equal to zero to satisfy the investor's constraint, and the VC would not accept this contract. Equation (A3) is easily shown to hold because the largest that θ_1^* and θ_2^* could be is one. Even in this case, as $\alpha \to 0$ Equation (A3) approaches

$$1 \geq \sqrt{\beta E[R_m] + \frac{1}{4}(1-\beta E[R_m])^2} + \frac{1}{2}(1-\beta E[R_m]), \tag{A4}$$

$$1 \geq \sqrt{\frac{1}{4} + \frac{1}{2}\beta E[R_m] + \frac{1}{4}\beta E[R_m]^2} + \frac{1}{2}(1-\beta E[R_m]) = 1. \tag{A5}$$

Therefore, both the VC and the entrepreneur would have to give up everything as $\alpha \to 0$. Because $e_{vc} > 0$, the VC would be unwilling to do so. Expected α must be large enough to provide for all.

Proof of Corollary 2. Part two of Theorem 2 shows that as long as $e_{vc}(\sigma_i^2) > 0$, then for small enough α the returns from the project would not be large enough to pay the VC and give the investor their required return.

Proof of Theorem 3. Assuming an economically reasonable equilibrium exists, then the constraint on the VC binds,

$$\theta_i \phi^* I \mu_i - \frac{1}{2} A I^2 (\theta_i \phi^*)^2 \sigma_i^2 = e_{vc}. \tag{A6}$$

Taking the total derivative with respect to the variance σ_i^2 and solving for $d\theta_i/d\sigma_i^2$ yields

$$\frac{d\theta_i}{d\sigma_i^2} = \frac{\frac{1}{2}AI^2\phi^{*2}\theta_i^2}{\left[\phi^* I\mu_i - AI^2\phi^{*2}\theta_i\sigma_i^2\right]}. \tag{A7}$$

The derivative is positive as long as

$$\phi^* I\mu_i - AI^2\phi^{*2}\theta_i\sigma_i^2 > 0. \tag{A8}$$

Earlier we assumed that increasing the fraction offered to the VC always improved his utility. Therefore, $\phi^* I\mu_i - AI^2\phi^{*2}\sigma_i^2 > 0$. Thus, as long as θ_i is economically reasonable (between zero and one), θ_i increases with variance, and variance increases with idiosyncratic risk, $\sigma_{\varepsilon_i}^2$. A greater fraction given up by the entrepreneur is equivalent to receiving a lower implicit value for the firm. Therefore, total gross returns are be higher. Thus, high gross returns are correlated with high idiosyncratic risk.

Proof of Corollary 3. Assuming there is no principal-agent problem and an economically reasonable equilibrium exists, then the constraint on the VC binds,

$$\theta_i\phi' I\mu_i = e_{vc}(\sigma_i^2). \tag{A9}$$

Taking the total derivative with respect to the variance σ_i^2 and solving for $d\theta_i/d\sigma_i^2$ yields

$$\frac{d\theta_i}{d\sigma_i^2} = \frac{e'_{vc}(\sigma_i^2)}{\phi' I\mu_i} \tag{A10}$$

The derivative is positive as long as $e'_{vc}(\sigma_i^2) > 0$.Thus, θ_i increases with variance, and variance increases with idiosyncratic risk, $\sigma_{\varepsilon_i}^2$. A greater fraction given up by the entrepreneur is equivalent to receiving a lower implicit value for the firm. Therefore, total gross returns are higher, and high gross returns are correlated with high idiosyncratic risk.

Proof of Corollary 4. Assuming an economically reasonable equilibrium exists, the net fraction owned by the investors equals $\theta'_i - \theta'_i\phi'$. Without the principal-agent problem we know

$$\phi = 1 - \frac{1}{\theta'_i\left(\mu_i - \beta_i E[R_m]\right)}, \tag{A11}$$

and

$$\phi' = \frac{e_{vc}(\sigma_i^2)}{\theta'_i I\mu_i}. \tag{A12}$$

Substitution reveals that

$$\theta'_i - \theta'_i\phi' = \frac{1}{(1+\alpha_i)}. \tag{A13}$$

Therefore, the fraction held by investors is NOT a function of $\sigma^2_{\varepsilon_i}$. Thus, in the model without a principal-agent problem, net returns are not correlated with realized idiosyncratic risk.

A.2 The general problem

This section shows that for some set of utility functions and exogenous model parameters (α's, β's, e_{vc}, *etc.*) a solution exists. We assume that the VC is risk averse but likes wealth so that $u'(w) > 0$ and $u''(w) < 0$. We also assume that the utility function is continuous in all parameters.

Let ϕ_p represent the contract negotiated with the investors, and let θ_p represent the vector of contracts negotiated with the entrepreneurs. Because the VC's wealth, w, depends on the fraction of the portfolio he receives, the VC's utility is a function of the negotiated fractions: $u(w(\phi_p, \theta_p))$. Furthermore, the fraction the VC receives is $\phi_p\theta_p$,; therefore, the VC's utility as a function of his fraction of the portfolio collapses to $u(\phi_p\theta_p)$. The last assumption we make is that the portfolio is sufficiently good so that more of the portfolio is better: $\frac{d}{d\phi_p\theta_p}u(\phi_p\theta_p) > 0$.

We assume for simplicity that the VC negotiates with all entrepreneurs at once. This is unnecessary but eliminates the need to take expectations over future project parameters. Because the VC's are competitive, the θ_i must all be set so that the VC's utility constraint binds:

$$u(\phi_p\theta_p) = e_{vc}. \tag{A14}$$

There is only one constraint and N degrees of freedom in θ_p, and $\frac{d}{d\phi_p\theta_p}u(\phi_p\theta_p) > 0$,; therefore, given a $\phi_p > 0$, there are an infinite number of solutions to this constraint. Because we are only trying to show that a solution exists, we focus on a symmetric solution in which $\theta_i = \theta_j$. If a symmetric solution exists, it is almost certain but irrelevant that other solutions also exist. Let $\theta^*_p > 0$ represent the symmetric fraction that is the solution to the VC's constraint ($\frac{d}{d\phi_p\theta_p}u(\phi_p\theta_p) > 0$ insures there is only one and that it is positive). Because each element of a solution vector would be the same, there is no longer a need for vector representation, and θ^*_p is simply a number.

Given the symmetric solution θ^*_p, and the competition among investors, ϕ_p must be set such that

$$E_{\Omega_{vc}}\left[\frac{\theta^*_p(1-\phi_p)\mu_p}{1+\theta^*_p(1-\phi_p)\beta_p E[R_m]}\right] = 1, \tag{A15}$$

where β_p is the beta of the portfolio. For any positive fraction θ^*_p, $E_{\Omega_{vc}}\left[\frac{\theta^*_p(1-\phi)\mu_p}{1+\theta^*_p(1-\phi)\beta_p E[R_m]}\right]$ is a strictly decreasing function of ϕ. Therefore, a solution to the constraint always exists for some parameters μ_p, β_p, and $E[R_m]$, unless $\theta^*_p = 0$, and we showed above that $\theta^*_p > 0$. Let ϕ^*_p represent the solution to the investor's constraint.

To show that a solution to the overall problem exists, we must show that the constraints cross in (θ_p, ϕ_p) space. In the limit as $\theta_p \to 0$, then for $u(\theta_p\phi_p) = e_{vc}$, $\phi_p \to \infty$. Furthermore, as $\theta_p \to \infty$, then for $u(\theta_p\phi_p) = e_{vc}$, $\phi_p \to 0$. Therefore, continuity of the utility function ensures isoutility curves in the positive quadrant of (θ_p, ϕ_p) space are convex parabolas that approach the x-axis and y-axis in the limit. Looking at the second constraint, Equation (A15), we see that as $\theta_p \to 0$, $\phi_p \to -\infty$ and as $\theta_p \to \infty$, $\phi_p \to 1$. Therefore, isopresent value curves are increasing and concave, and we have achieved single crossing in the positive quadrant. Thus, we have proved that there is always only one symmetric solution. Furthermore, increasing β_p shifts up the isopresent value line up and decreasing e_{vc} shifts down the isoutility curve. Therefore, for some choice of parameters the single crossing occurs such that $0 < \theta_p^* < 1$ and $0 < \phi_p^* < 1$.

Proof of Theorem 5. The VC's payoff can be rewritten as

$$X_{vc} = y + \sigma_p \omega I \max[\frac{R_p - \mu_p - (R_b - \mu_p)}{\sigma_p}, 0] \; if \; R_b \geq 0, \tag{A16}$$

$$X_{vc} = y + \omega I R_b + \sigma_p \omega I \max[\frac{R_p - \mu_p - (R_b - \mu_p)}{\sigma_p}, 0] \; if \; R_b < 0,$$

or,

$$X_{vc} = y + \sigma_p \omega I \max[z - \frac{R_b - \mu_p}{\sigma_p}, 0] \; if \; R_b \geq 0, \tag{A17}$$

$$X_{vc} = y + \omega I R_b + \sigma_p \omega I \max[z - \frac{R_b - \mu_p}{\sigma_p}, 0] \; if \; R_b < 0,$$

where $z \sim N(0, 1)$. Therefore, the VC's expected utility is

$$E[u(w)] = \int_{-\infty}^{\frac{R_b - \mu_p}{\sigma_p}} u(y) f(z) dz + \int_{\frac{R_b - \mu_p}{\sigma_p}}^{\infty} u(y + \sigma_p \omega I z - \omega I (R_b - \mu_p)) f(z) dz \; if \; R_b \geq 0, \tag{A18}$$

$$E[u(w)] = \int_{-\infty}^{\frac{R_b - \mu_p}{\sigma_p}} u(y + \omega I R_b) f(z) dz + \int_{\frac{R_b - \mu_p}{\sigma_p}}^{\infty} u(y + \sigma_p \omega I z + \omega I \mu_p) f(z) dz \; if \; R_b < 0.$$

The derivative of each expected utility with respect to variance of the portfolio is

$$\frac{d}{d\sigma_p} E[u(w)] = \int_{\frac{R_b - \mu_p}{\sigma_p}}^{\infty} u'(y + \sigma_p \omega I z - \omega I (R_b - \mu_p)) f(z) dz \; if \; R_b \geq 0, \tag{A19}$$

$$\frac{d}{d\sigma_p} E[u(w)] = \int_{\frac{R_b - \mu_p}{\sigma_p}}^{\infty} u'(y + \sigma_p \omega I z + \omega I \mu_p) f(z) dz \; if \; R_b < 0.$$

Thus, if $R_b - \mu_p \geq 0$, then $\frac{d}{d\sigma_p}E[u(w)] > 0$. Furthermore, if $R_b - \mu_p < 0$, then[30]

$$\lim_{R_b \to -\infty} \frac{d}{d\sigma_p} E[u(w)] = E[u'(y + \sigma_p \omega I z + \omega I \mu_p)] < 0. \tag{A20}$$

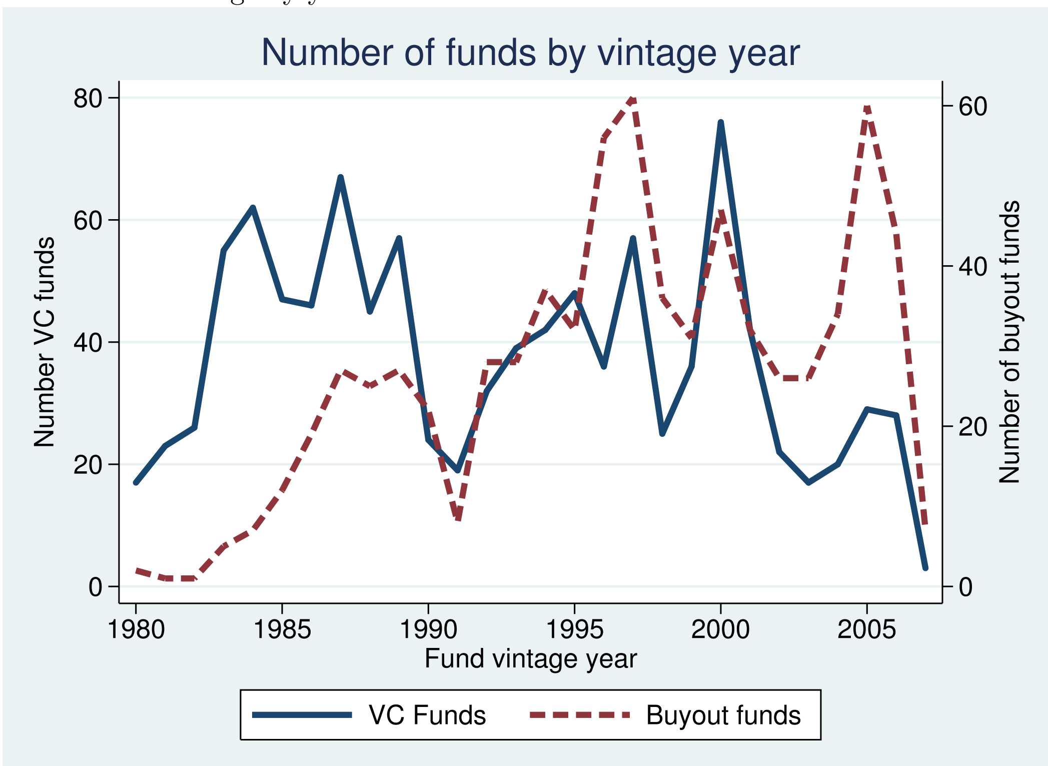
Therefore, continuity implies that $\frac{d}{d\sigma_p}E[u(X_{vc})] = 0$for some R_b such that $-\infty < R_b < \mu_p$.

[30] The proof that $E[u'(y + \sigma_p \omega I z + \omega I \mu_p)] < 0$ is as follows.

Let $x \sim N(0, 1)$. Then if $x > 0$, then $u'(a+x) < u'(a)\ \forall a \Rightarrow u'(a+x)x < u'(a)x\ \forall a$. If $x < 0$, then $u'(a+x) > u'(a)\ \forall a \Rightarrow u'(a+x)x < u'(a)x\ \forall a$ (remember $x < 0$ so inequality switches). Therefore, $u'(a+x)x < u'(a)x$ $\forall a, x \Rightarrow E[u'(a+x)] < u'(a)E[x] = 0$.

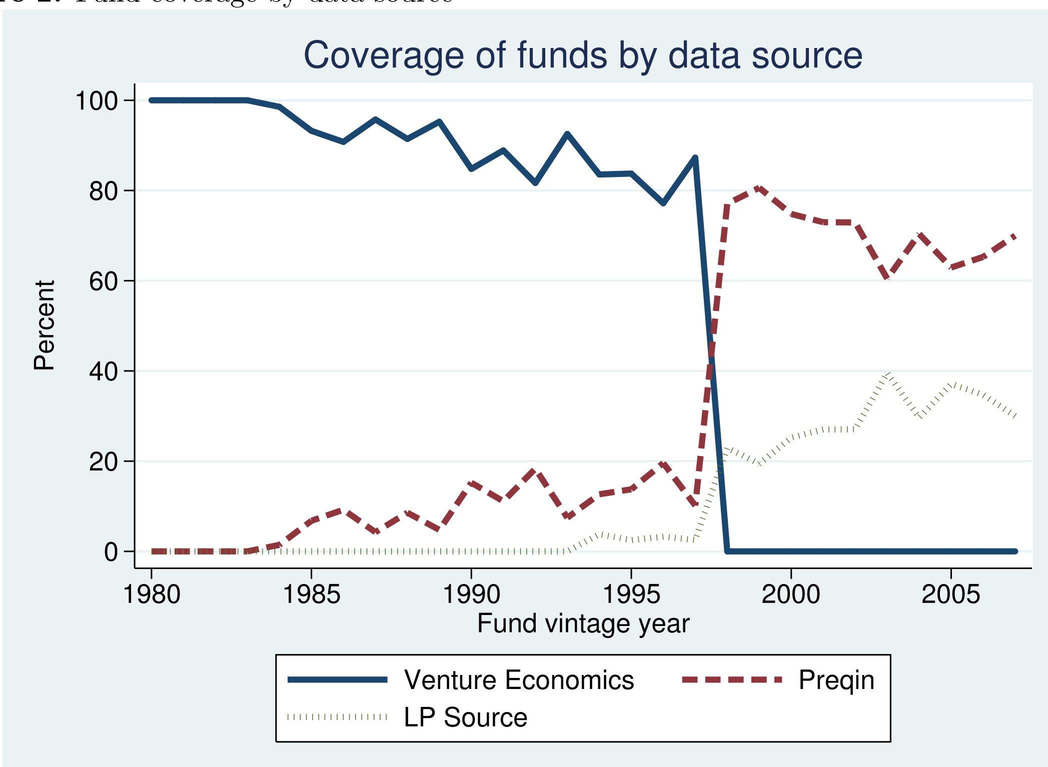
Tables and Figures

Figure 1. Fund coverage by year



This figure reports the number of buyout and VC funds by vintage year available in the merged data of Venture Economics, Preqin, and LP Source.

Figure 2. Fund coverage by data source



This figure reports the fraction of coverage of funds by vintage year by data source: Venture Economics, Preqin, and LP Source.

Table 1. Summary statistics of funds

This table reports the characteristics of funds and the source of data for the VC and buyout funds included in the main empirical specification (10) estimated in Table 4 (i.e., at least 16 quarters of returns, vintage years $\in [1980, 2007]$). "Fund size" is the total capital committed in 2010 dollars. "Fund vintage year" is the year the fund was formed. "Total distributions" are the total number of quarters in which the fund had a distribution to the limited partner (or total distributions if data source in Venture Economics). "Total takedowns" are the total number of quarters in which there was a call of capital from the LP to the fund (or total takedowns in data source is Venture Economics). "Percent early stage" is the fraction of VC funds in the sample that are labeled as investing in early-stage entrepreneurial investments. "Percent late stage" is the equivalent but for late-stage investments. "Percent balanced funds" is the fraction of funds that invest in all stages of entrepreneurial firms. "Percent VE funds" reports the fraction of funds whose cash flow and valuation data are from Venture Economics ("Preqin" and "LP Source" analogous for other possible data sources). "Annualized size-weighted IRR" is the average annualized IRR for each fund type, weighted by fund size. The "equal-weighted" version averages across all funds.

	VC funds			Buyout funds		
	Mean	SD	Median	Mean	SD	Median
Fund size (m, 2010)	245.90	370.747	118.15	1,298.78	2,359.027	530.09
Fund vintage year	1992.46	7.262	1992.50	1996.81	6.277	1997.00
Total distributions	17.99	86.872	12.00	21.76	22.613	16.00
Total takedowns	14.58	39.519	11.00	22.56	18.124	19.00
Percent early stage	39.81	48.974	0.00			
Percent late stage	14.13	34.855	0.00			
Percent balanced funds	44.81	49.754	0.00			
Percent VE funds	68.37	46.527	100.00	42.65	49.489	0.00
Percent LP Source funds	7.79	26.812	0.00	15.52	36.234	0.00
Percent Preqin funds	23.85	42.635	0.00	41.84	49.362	0.00
Annualized size-weighted IRR	13.61	30.693	5.11	13.84	44.451	9.35
Annualized equal-weighted IRR	15.27	37.131	6.43	13.24	29.109	10.37
Observations	1,040			741		

Table 2. Estimates from market regressions by fund type

Sample includes 1,040 buyout and 1040 VC funds raised between 1980–2007 from the merged dataset of Venture Economics, Preqin, and LP Source (detailed in Section 3.1). Funds must have at least 16 quarters of returns to be in the sample. Funds are sorted into quartiles based on fund size (in 2010 U.S. dollars). The table reports the estimates from the time-series regressions of the following form

$$r_{it} = \alpha_i + \beta_{0i} r_{mt} + \beta_{1i} r_{m,t-1} + \ldots + \beta_{4i} r_{m,t-4} + \varepsilon_{it},$$

where i represents fund type (buyout or VC). r_{it} is the excess quarterly return to the fund, and $r_{m,t-k}$ is the quarterly excess return for the market index for k quarters prior to t. Portfolio returns are value-weighted. Each observation in the data is weighted by the number of active funds in the same quarter. "Contemporaneous ($j = 0$)" is $\hat{\beta}_{i,0}$, and each "Lag k quarter(s)" is the estimate $\beta_{i,\hat{t-k}}$. Robust standard errors are in parentheses. "$\sum \beta$" reports the sum of the full set of coefficient estimates. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	All funds	VC funds	Buyout funds
α	0.00640	-0.00177	0.0115*
	(0.00515)	(0.00749)	(0.00489)
Contemporaneous ($j = 0$)	0.316***	0.372***	0.298***
	(0.0531)	(0.0769)	(0.0506)
Lag 1 quarter ($j = 1$)	0.205***	0.237**	0.170**
	(0.0541)	(0.0782)	(0.0517)
Lag 2 quarters ($j = 2$)	0.156**	0.186*	0.127*
	(0.0543)	(0.0783)	(0.0520)
Lag 3 quarters ($j = 3$)	0.0971	0.180*	0.0334
	(0.0545)	(0.0788)	(0.0521)
Lag 4 quarters ($j = 4$)	0.154**	0.259**	0.0960
	(0.0559)	(0.0806)	(0.0536)
$\sum \beta$	0.929***	1.234***	0.724***
SE	(0.121)	(0.179)	(0.112)
R^2	0.361	0.300	0.324

Table 3. Funds sorted by size

Sample includes 1,040 buyout and 1040 VC funds raised between 1980–2007 from the merged dataset of Venture Economics, Preqin, and LP Source (detailed in Section 3.1). Funds are sorted into quartiles based on fund size (in 2010 U.S. dollars). The table reports the estimates from the following three-factor (lagged) time-series regression

$$r_{it} = \alpha_i + \sum_{k=0}^{4} \beta_{ik}^{RMRF} r_{t-k}^{RMRF} + \sum_{k=0}^{4} \beta_{ij}^{SMB} r_{t-k}^{SMB} + \sum_{k=0}^{4} \beta_{ik}^{HML} r_{t-k}^{HML} + \epsilon_{it},$$

where i represents a size quartile. Quarterly portfolio returns within quartile are value-weighted and the regression weights observations by the number of active funds in the quarter. "$\sum \beta^j$" reports the sum of the five coefficients on the particular factor, with SE of the sum and reported p-value from a null of zero. "Avg. Size (m)" is the average size of funds (in 2010 U.S. dollars) within the quartile. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Panel A: Venture capital funds					
		Size quartile			
	All	1 (Smallest)	2	3	4 (Largest)
α	0.00487	0.00415	-0.00971	-0.000891	0.00974
	(0.00629)	(0.00948)	(0.0122)	(0.00920)	(0.00676)
$\sum \beta^{RMRF}$	1.051***	0.275	0.825**	1.254***	1.077***
SE	(0.108)	(.189)	(0.257)	(0.18)	(0.119)
$\sum \beta^{SMB}$	-0.067	0.053	-0.072	-0.887***	0.302
SE	(0.16)	(0.261)	(0.356)	(0.258)	(0.178)
$\sum \beta^{HML}$	-0.879***	-0.569**	-0.873***	-0.595***	-0.976***
SE	(0.105)	(0.181)	(0.25)	(0.177)	(0.117)
Avg. Size (m)	198.92	40.8	93.98	167.8	486
R^2	0.609	0.163	0.375	0.475	0.567

Panel B: Buyout funds					
		Size quartile			
	All	1 (Smallest)	2	3	4 (Largest)
α	0.00935*	0.0174**	0.0130*	0.00220	0.0117*
	(0.00529)	(0.00721)	(0.00763)	(0.00595)	(0.00668)
$\sum \beta^{RMRF}$	0.816***	0.343*	0.526***	0.802***	1.015***
SE	(0.073)	(0.119)	(0.127)	(0.088)	(0.105)
$\sum \beta^{SMB}$	0.088	-0.204	-0.357	0.143	0.155
SE	(0.141)	(0.206)	(0.225)	(.167)	(0.192)
$\sum \beta^{HML}$	0.236*	0.21	0.065	0.239	0.294*
SE	(0.079)	(0.125)	(0.137)	(0.096)	(0.114)
Avg. Size (m)	1,187.14	157.8	376.43	807.6	3,295.8
R^2	0.370	0.163	0.151	0.328	0.417

Table 4. Funds sorted by idiosyncratic risk

Sample includes 1,040 buyout and 1040 VC funds raised between 1980–2007 from the merged dataset of Venture Economics, Preqin, and LP Source (detailed in Section 3.1) that have at least 16 quarters of returns. The first stage—not reported in the table—estimates the following regression for each of these funds:

$$r_{it} = \alpha_i + \sum_{k=0}^{4} \beta_{ik}^{RMRF} r_{t-k}^{RMRF} + \sum_{k=0}^{4} \beta_{ij}^{SMB} r_{t-k}^{SMB} + \sum_{k=0}^{4} \beta_{ik}^{HML} r_{t-k}^{HML} + \epsilon_{it},$$

where r_{it} is the excess return measured for each quarter, and r_{ik}^{j} are the standard three-factor returns. The root-mean-squared error (RMSE) for each fund i is saved from each regression. These RMSEs are then sorted, and value-weighted portfolios are formed by quartile. The resulting portfolio returns are again estimated using the above specification, where each quarter is weighted by the number of funds with returns. $\sum \beta^{RMRF}$ and others report the sum of the $\beta_{r,t-k}$ for $k \in [0, 4]$. The "Avg. RMSE" is the average fund RMSE within each quartile, weighted by fund size. Robust standard errors are in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Panel A: Venture capital funds			
	RMSE quartile			
	1	2	3	4
α	-0.0160***	0.00603	0.00146	0.0255**
	(0.00563)	(0.00924)	(0.0112)	(0.0128)
R^2	0.607	0.458	0.481	0.513
$\sum \beta^{RMRF}$	0.861***	0.76***	0.897***	1.132**
SE	(0.147)	(0.224)	(0.219)	(0.469)
$\sum \beta^{SMB}$	0.711**	-0.106	0.134	-0.835**
SE	(0.258)	(0.29)	(0.26)	(0.374)
$\sum \beta^{HML}$	-0.87***	-0.74***	-0.86**	-0.951**
SE	(0.182)	(0.168)	(0.293)	(0.35)
Avg. RMSE	0.03	0.08	0.12	0.33

	Panel B: Buyout funds			
	RMSE quartile			
	1	2	3	4
α	-0.00219	-0.00313	0.0133**	0.0146
	(0.00454)	(0.00473)	(0.00654)	(0.0105)
R^2	0.656	0.487	0.332	0.162
$\sum \beta^{RMRF}$	0.466***	0.762***	0.682***	0.984***
SE	(0.106)	(0.157)	(0.15)	(0.343)
$\sum \beta^{SMB}$	0.228	0.253	-0.103	0.326
SE	(0.107)	(0.154)	(0.171)	(0.507)
$\sum \beta^{HML}$	0.19**	0.2	0.09	0.46
SE	(0.03)	(0.073)	(0.088)	(0.262)
Avg. RMSE	0.03	0.07	0.12	0.4

Table 5. Funds sorted by idiosyncratic risk: Pre-2003 funds

Sample includes 485 buyout and 879 VC funds raised between 1980–2002 from the merged dataset of Venture Economics, Preqin, and LP Source (detailed in Section 3.1) that have at least 16 quarters of returns. The first stage—not reported in the table—estimates the following regression for each of these funds:

$$r_{it} = \alpha_i + \sum_{k=0}^{4} \beta_{ik}^{RMRF} r_{t-k}^{RMRF} + \sum_{k=0}^{4} \beta_{ij}^{SMB} r_{t-k}^{SMB} + \sum_{k=0}^{4} \beta_{ik}^{HML} r_{t-k}^{HML} + \epsilon_{it},$$

where r_{it} is the excess return measured for each quarter, and r_{ik}^{j} are the standard three-factor returns. The root-mean-squared error (RMSE) for each fund i is saved from each regression. These RMSEs are then sorted, and value-weighted portfolios are formed by quartile. The resulting portfolio returns are again estimated using the above specification, where each quarter is weighted by the number of funds with returns. $\sum \beta^{RMRF}$ and others report the sum of the $\beta_{r,t-k}$ for $k \in [0,4]$. The "Avg. RMSE" is the average fund RMSE within each quartile, weighted by fund size. Robust standard errors are in parentheses. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Panel A: Venture capital funds				
	RMSE quartile			
	1	2	3	4
α	-0.0120**	0.00814	0.0128	0.0232
	(0.00551)	(0.0108)	(0.0145)	(0.0140)
R^2	0.689	0.541	0.396	0.520
$\sum \beta^{RMRF}$	0.694***	0.86***	0.706*	1.222**
SE	(0.12)	(0.261)	(0.354)	(0.564)
$\sum \beta^{SMB}$	0.463*	0.079	0.134	-1.113**
SE	(0.209)	(0.277)	(0.342)	(0.434)
$\sum \beta^{HML}$	-0.92***	-0.92***	-1.03**	-0.951**
SE	(0.15)	(0.175)	(0.369)	(0.426)
Avg. RMSE	0.04	0.09	0.13	0.35

Panel B: Buyout funds				
	RMSE quartile			
	1	2	3	4
α	-0.0109***	-0.00240	0.00392	0.0120
	(0.00348)	(0.00426)	(0.00822)	(0.00877)
R^2	0.399	0.449	0.317	0.196
$\sum \beta^{RMRF}$	0.406***	0.66***	0.772***	0.634**
SE	(0.099)	(0.106)	(0.162)	(0.26)
$\sum \beta^{SMB}$	0.122	0.139	-0.133	0.02
SE	(0.046)	(0.101)	(0.182)	(0.313)
$\sum \beta^{HML}$	0.12	0.08	0.03	0.16
SE	(0.027)	(0.043)	(0.12)	(0.17)
Avg. RMSE	0.04	0.08	0.13	0.42

Table 6. RMSE and fund characteristics

Summary of fund characteristics across the root-mean-squared error (i.e., idiosyncratic risk) quartiles from fund-level Fama-French three-factor regression. "Fund size (m)" is the total capital committed to the fund in 2010 U.S. dollars (m). "Fund vintage year" is the year the fund formed. "Fund sequence #" is the sequence number of the fund. "Early-stage fund" is equal to one if the fund invests in early-stage entrepreneurial firms, so mean reports the fraction of funds within the quartile that make such investments. "Late-stage fund" is equal to one if the fund investments in late-stage financings and "VC inflows in year" sums all capital invested in entrepreneurial firms in the fund's vintage year. "Buyout inflows in year" is the sum of total capital raised in LBOs in a vintage year. Significance: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	VC funds RMSE quartile				
	1	2	3	4	Total
Fund size (m)	332.5	211.9	158.4	133.4	196.9
Fund vintage year	1994.4	1989.9	1988.0	1987.7	1989.6
Fund sequence #	1.670	1.854	1.937	2.046	1.898
Early-stage fund	0.377	0.366	0.398	0.396	0.386
Late-stage fund	0.145	0.122	0.180	0.116	0.141
VC inflows in year	2,8461.7	1,6793.1	6,536.1	5,245.8	12,787.7

	Buyout funds RMSE quartile				
	1	2	3	4	Total
Fund size (m)	1,727.9	1,308.6	1,002.8	800.1	1,155.5
Fund vintage year	1999.2	1995.6	1994.5	1992.0	1994.9
Fund sequence #	1.860	1.830	1.720	1.620	1.744
Buyout inflows in year	83,345.9	48,768.5	44,758.7	33,183.3	49,589.6

Table 7. Portfolio alphas sorted by fund characteristics and idiosyncratic risk

Sample includes the 1,040 buyout and 1040 VC funds raised between 1980–2007 from the merged dataset of Venture Economics, Preqin, and LP Source (detailed in Section 3.1) that have at least 16 quarters of returns. After estimating individual time-series regressions of three-factor model for each fund, the RMSE and fund size are used to create portfolios. Funds are first sorted by each observable (detailed in Table 6) into quartiles and then sorted by RMSE. Portfolios are created with returns value-weighted in the following regression:

$$r_{it} = \alpha_i + \sum_{k=0}^{4} \beta_{ik}^{RMRF} r_{t-k}^{RMRF} + \sum_{k=0}^{4} \beta_{ij}^{SMB} r_{t-k}^{SMB} + \sum_{k=0}^{4} \beta_{ik}^{HML} r_{t-k}^{HML} + \epsilon_{it},$$

where r_{it} is the excess return measured for each quarter, and r_{ik}^{j} are the standard three-factor returns.. Each cell in the table shows the estimate of α with its standard error. "4-1" reports the difference in α estimates between the top and bottom RMSE quartile within each size quartile. The significance stars present the variance p-value results from a one-side test that the high RMSE quartile α is greater than the low RMSE quartile α. t-statistics are in brackets. Significance from a one-sided test of α from the top and bottom quartile: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Panel A: Venture capital funds				
Size quartile	RMSE quartile				
	1	2	3	4	$4-1$
1	-0.008 [-4.25]	0.004 [0.41]	-0.006 [-0.52]	0.026 [0.75]	0.0345***
2	-0.016 [-1.96]	-0.032 [-2.74]	0.011 [0.51]	0.006 [0.20]	0.0217
3	-0.004 [-0.51]	0.010 [1.14]	0.026 [2.58]	0.034 [1.26]	0.038*
4	-0.005 [-0.85]	0.001 [0.22]	0.003 [0.43]	0.014 [1.28]	0.0188**
Controlling for:					
Fund size	-0.012 [-3.03]	-0.009 [-1.48]	0.006 [0.80]	0.019 [1.52]	0.0307***
Fund sequence	-0.013 [-2.96]	0.005 [0.85]	0.008 [0.90]	0.014 [1.09]	0.0269**
Vintage year	-0.008 [-2.09]	-0.004 [-0.89]	-0.000 [-0.04]	0.020 [2.53]	0.0276***
Total inflows	-0.009 [-1.76]	-0.010 [-1.87]	0.009 [1.46]	0.020 [1.66]	0.029***
Fund inv. stage	-0.011 [-2.25]	-0.001 [-0.16]	0.012 [1.29]	0.023 [1.95]	0.0337***
	Panel B: Buyout funds				
Size quartile	RMSE quartile				
	1	2	3	4	$4-1$
1	-0.024 [-5.21]	0.016 [1.98]	0.011 [0.86]	0.022 [1.23]	0.0459***
2	-0.003 [-0.66]	0.000 [0.07]	0.021 [2.45]	0.020 [1.88]	0.023***
3	-0.001 [-0.23]	-0.005 [-0.92]	0.011 [1.07]	0.043 [1.73]	0.0433***
4	0.006 [1.38]	0.009 [1.37]	0.019 [2.19]	0.018 [0.95]	0.0124
Controlling for:					
Fund size	-0.007 [-2.76]	0.005 [1.19]	0.014 [2.57]	0.022 [2.40]	0.0291***
Fund sequence	-0.005 [-1.73]	0.002 [0.43]	0.016 [2.79]	0.019 [1.39]	0.0239***
Vintage year	0.000 [0.04]	-0.000 [-0.03]	0.017 [2.80]	0.028 [2.45]	0.0281***
Total inflows	-0.004 [-1.39]	-0.001 [-0.33]	0.020 [3.56]	0.022 [1.33]	0.0261**

Table 8. Cross section regression of quarterly returns

Estimates from a Fama-MacBeth regression of VC and buyout fund quarterly returns on fund observables. For each of the 127 quarters (four excluded because of lag structure), we estimate a cross-sectional regression of fund returns on controls and estimates of idiosyncratic volatility from a three-factor model. Both the level—"Idiosyncratic volatility"—and dummies for RMSE quartiles within each fund vintage year are included (Columns (1) and (2)). "Quarterly return $t-1$" is the lagged fund return, "Early-stage fund" and "Late-stage fund" are dummies for the investment type of the fund, and "Fund #" is a dummy for the sequence of the fund. "Fund age" is the log of the age of the fund (+1) as of t. "Log fund size" is the log of the fund committed capital in 2010 U.S. dollars. "Log market inflows in vintage year (m)" is the log of total dollars invested in the VC or buyout markets for the fund's vintage (in 2010 dollars). Standard errors are in parentheses, corrected for heteroscedasticity using Newey-West's two-lag estimator; significance * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Venture capital funds		Buyout funds	
	(1)	(2)	(3)	(4)
Idiosyncratic vol.	0.257***		0.224***	
	(0.0851)		(0.0444)	
RMSE quartile 2		0.00763***		0.0225*
		(0.00272)		(0.0120)
RMSE quartile 3		0.0118***		0.0284***
		(0.00429)		(0.00736)
RMSE quartile 4		0.0556***		0.0933***
		(0.0133)		(0.0143)
Quarterly return $t-1$	-0.0790	-0.111	0.0213	0.106
	(0.0550)	(0.0716)	(0.0628)	(0.0988)
Quarterly return $t-2$	0.0151	0.0268	0.0633*	-0.0829
	(0.0355)	(0.0344)	(0.0369)	(0.131)
Early-stage fund	-0.000520	0.00387		
	(0.00410)	(0.00458)		
Late-stage fund	0.00748	0.00952		
	(0.00576)	(0.00608)		
Fund #1	-0.00656	-0.00761	-0.00441	0.00592
	(0.00544)	(0.00669)	(0.0133)	(0.0149)
Fund #2	-0.00557	-0.00645	-0.00743	-0.00554
	(0.00372)	(0.00417)	(0.0142)	(0.0138)
Funds #3 and #4	-0.0106**	-0.0113**	-0.00237	-0.00369
	(0.00459)	(0.00465)	(0.0119)	(0.0117)
Fund # > 4	-0.000426	-0.00243	-0.0133	-0.00485
	(0.00409)	(0.00418)	(0.00947)	(0.00649)
Log fund size	0.00715***	0.00632**	0.00666*	0.00798*
	(0.00192)	(0.00314)	(0.00363)	(0.00436)
Log market inflows in vintage year (m)	-0.00308	-0.00370	0.000798	-0.00492
	(0.00445)	(0.00458)	(0.00716)	(0.00767)
Observations	38,258	38,258	19,560	19560
R^2	0.169	0.177	0.227	0.235
Number of quarters	123	123	123	123

Table 9. Cross section regression of quarterly returns: Stale NAV control

Estimates from a Fama-MacBeth regression of VC fund quarterly returns on fund observables. For each of the 127 quarters (four excluded because of lag structure), we estimate a cross-sectional regression of fund returns on controls and estimates of idiosyncratic volatility from a three-factor model. Both the level—"Idiosyncratic volatility"—and dummies for RMSE quartiles within each fund vintage year are included (Columns (1) and (2)). "Quarterly return $t-1$" is the lagged fund return, "Early-stage fund" and "Late-stage fund" are dummies for the investment type of the fund and "Fund #" is a dummy for the sequence of the fund. "Fund age" is the log of the age of the fund (+1) as of t. "Log fund size" is the log of the fund committed capital in 2010 dollars. "Log market inflows in vintage year (m)" is the log of total dollars invested in the VC or buyout markets for the fund's vintage (in 2010 dollars). "% flat NAV" is the fraction of flat quarterly returns or stale NAVs. Standard errors are in parentheses, corrected for heteroscedasticity using Newey-West's two-lag estimator; significance * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

	Venture capital funds	
	(1)	(2)
Idiosyncratic vol.	0.249***	
	(0.0853)	
RMSE quartile 2		0.00758***
		(0.00269)
RMSE quartile 3		0.0113***
		(0.00370)
RMSE quartile 4		0.0549***
		(0.0134)
Quarterly return $t-1$	-0.0871	-0.121*
	(0.0533)	(0.0674)
Quarterly return $t-2$	-0.00470	0.0128
	(0.0436)	(0.0416)
Early-stage fund	-0.000434	0.00328
	(0.00408)	(0.00468)
Late-stage fund	0.00774	0.0108*
	(0.00571)	(0.00608)
Fund #1	-0.00728	-0.00866
	(0.00629)	(0.00824)
Fund #2	-0.00653	-0.00754
	(0.00479)	(0.00552)
Funds #3 and #4	-0.0117**	-0.0110**
	(0.00473)	(0.00453)
Fund # >4	-0.000716	-0.00195
	(0.00245)	(0.00239)
Log fund size	0.00681***	0.00695**
	(0.00204)	(0.00291)
Log market inflows in vintage year (m)	-0.00337	-0.00298
	(0.00452)	(0.00475)
% flat NAV	0.0194	0.0653
	(0.0266)	(0.0471)
Observations	38,100	38,100
R^2	0.182	0.189
Number of quarters	123	123