Does Risk Explain Persistence in Private Equity Performance?*

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Abstract

In this paper, we investigate whether fund-specific risk helps explain performance persistence in private equity funds, using detailed deal-level cash flow information at both the fund and deal levels. We further extend existing findings to international evidence on buyout and venture capital (VC) by testing the impact of various risk measures. We find that risk is an important driver of performance persistence and helps explain such persistence. We also find persistence in risk in private equity, in particular persistence in downside volatility for both buyout and VC funds. Finally, we document that fund performance is more strongly affected by fund managers able to minimize downside losses than selecting outperforming portfolio companies. This effect is strongest for buyout but, to a weaker extent, also holds for VC.

Keywords: private equity; performance; venture capital; buyout; risk

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1. INTRODUCTION

Since Kaplan and Schoar's (2005) seminal article on fund performance persistence in US private equity (PE), several follow-up studies have investigated drivers of this persistence. For example, Harris, Jenkinson, Kaplan and Stucke (2014) find that performance persistence has largely disappeared in the buyout but not venture capital (VC) segment. In contrast, Korteweg and Sorensen (2014) find greater long-term persistence in buyout than in VC due to larger differences in skills among buyout fund managers. The question whether there is persistence in fund performance is important because it implies that some fund managers consistently outperform their peers over a longer period and, thus, that past performance is a good predictor of future performance.

This study contributes to this debate by examining the impact of deal-level characteristics, using detailed deal-level and fund-level cash flow data coming from the Center for Private Equity Research (CEPRES) database. Our international sample covers 18,256 unique investments in portfolio companies done by 769 VC and buyout funds during the 1980–2009 period. Slightly more than half the investments are realized (i.e., divested). Although portfolio companies are anonymized, the database enables linking portfolio companies to funds and funds to management firms. Previous versions of the data have been used by Franzoni, Nowak and Phalippou (2012) for buyout and Cumming, Schmidt, and Walz (2010), Cumming and Walz (2010) and Krohmer, Lauterbach and Calanog (2009) for VC. In contrast, our sample covers a larger time span and both types of private equity (VC and buyout). Moreover, we make use of information at both the deal and fund levels.

Using these data, we assess whether risk can explain the observed persistence in performance. Previous studies have not investigated this issue because of a lack of accurate deal-level data. However, Kaplan and Schoar (2005) recognized that risk might help explain persistence, but they could not investigate it further beyond examining potential differences across subsamples of fund asset classes to capture differences in risk between funds. Fund-level cash flows are indeed not appropriate for measuring risk, because there is a strong cash flow pattern over time in the 10-year life cycle of private equity funds. This pattern occurs because cash flows are lower at the beginning and increase significantly toward the end. In contrast, we make use of deal-level cash flows, which allow us to calculate the volatility of the internal rates of return (IRRs) of the different deals to measure risk at the fund level. This approach helps us investigate the following research questions: do differences in risk explain the fund performance persistence puzzle in private equity? Moreover, in addition to performance persistence, can we observe persistence in risk over follow-up funds? More generally, is fund performance driven by managers able to consistently "minimize extreme losses" (i.e., downside volatility) or "select outperforming deals" (i.e., generate upside volatility)? Both effects affect performance, but in different ways. We investigate these research questions for VC and buyout funds located both in the United States and internationally.

Our primary measure of risk is intra-fund volatility, which represents the standard deviation of IRRs of the different portfolio companies in which a fund has invested over its lifetime. We further consider upward and downward intra-fund volatility to examine the impact of upside and downside risk on fund performance. Consistent with existing studies, we use the Public Market Equivalent (PME) ratio as our main measure of fund performance. PME uses a

market index of similar risk to scale a fund's market value and thus is a risk-adjusted performance measure (i.e., adjusted for systematic risk but not total risk). Our results, however, also hold for IRR, which is a measure of absolute returns. In other words, we examine the impact of total risk on fund performance, which is an appropriate measure for studying persistence in performance and risk.

We find that total fund risk is an important driver of performance in the US, even for risk-adjusted performance. We find no persistence in non-US funds. Total risk explains away the previously documented performance persistence for the US, especially for buyout funds. For US VC funds, performance persistence remains, while total fund risk is also a significant driver. Next, we find strong persistence in risk, consistent with the view that performance persistence goes hand in hand with persistence in risk. This finding offers an alternative and complementary explanation for performance persistence to the traditional one based on expertise. This relationship is again strongest for US funds. When evaluating downside and upside risk separately, we find contrasted results for US and non-US funds.

Prompted by these findings, we next investigate whether fund performance is driven by a strategy of "minimizing extreme losses" or "generating outperforming ventures", an issue that is particularly important for VC. Indeed, fund managers may generate high performance for two reasons: either because they are able to minimize total losses, notably by selecting targets that do not appear too risky, or because they are able to select the most promising firms in the industry and thereby ensure that at least one investment generates a very high return. In the first case, performance is high because downside risk is minimized; in the second case, performance is high because the fund has a "star" included in its portfolio (leading to higher

upward volatility). Our analysis indicates that managing downside risk has the greatest impact on fund performance. Consistent with our intuition, this finding is strongest for buyout funds, for which target companies are more mature and typically require corporate restructuring. For VC funds, the impact of upside risk is more important than for buyout funds, because VC investments are prone to more upside gains owing to the highly innovative and high-growth-oriented firms in which VC funds invest.

Our study contributes to the literature on fund performance in private equity.[1] To the best of our knowledge, the only study that directly links fund performance to deal-level characteristics is that by Braun, Jenkinson and Stoff (2013). However, they are unable to relate portfolio companies to specific funds so that they construct "synthetic funds" by bundling a series of sequential investments. In contrast with their approach, we are able to allocate every portfolio company investment to a specific fund, for which we also have detailed fund information. Thus, we have extensive information on management firms, funds and portfolio companies and can relate each company to a fund and each fund to a management firm. This allows us to construct precise measures of risk and extend our understanding using new information. Franzoni et al. (2012) examine a driver of abnormal returns (the "alpha") in private equity and find that it is explained by its liquidity risk premium. This result suggests that risk specific to private equity helps explain differences in returns between private and public equity. However, these authors do not examine persistence over time.

[1] A different research question often addressed in this literature is whether private equity yields a premium over public equity (Kaplan and Schoar, 2005; Phalippou and Gottschalg, 2009; Harris, Jenkinson and Kaplan, 2014). This requires cash flows net of fees. We have cash flows gross of fees, so we do not address this question here.

Marquez, Nanda and Yavuz (2014) offer a theoretical contribution into this literature by developing a model to explain why performance persistence is in equilibrium. They argue that top-performing fund managers may voluntarily limit fund size and fees to generate more value in the selected portfolio companies than other fund managers. As a result, funds of top-performing managers become over-subscribed but also show persistence in performance.

The remainder of the paper is structured as follows: the next section describes the data, defines our risk measures used and presents our sample. Section 3 analyzes drivers of fund performance and the impact of risk on performance persistence. We further examine persistence in risk. Section 4 concludes.

2. DATA DESCRIPTION, RISK MEASURES AND SAMPLE COMPOSITION

2.1. Data Description

We use data from the CEPRES database, which is unique in that it provides detailed information and cash flow data at deal and fund levels; other databases tend to provide data for private equity at either the fund level or the investment level only. CEPRES data are described in detail in Franzoni et al. (2012). Several studies have used the database, including Cumming, Schmidt and Walz (2010), Cumming and Walz (2010), Franzoni et al. (2012), and Krohmer, Lauterbach and Calanog (2009).

Through its special data collection method (based on the so-called Private Equity Analyzer), CEPRES effectively anonymizes all information related to investments to meet the confidentiality requirements of the VC and PE firms that provide data to CEPRES. This means

that third parties are not able to identify individual portfolio companies, funds or management firms. This is crucial and eliminates the incentives for management firms to overstate the results they report to CEPRES. Lack of anonymity in other databases may result in overstating, partial reporting and back-filling of information, amounting to positive self-reporting biases. We have details on 392 buyout funds that invested in 6,702 deals, 3,729 of which are fully realized deals. We also observe 377 VC funds that invested in 11,554 deals, 6,005 of which are fully realized deals. Our sample covers deals made during the period from January 1980 to the end of 2008, for which we have cash flow data until December 2009.

Figure 1 depicts the number of buyout and VC funds by vintage year. It shows that our sample is consistent with the general view that only a few VC and buyout funds were set up during the 1980s and early 1990s compared with later years. Just before the dot.com bubble, the number of VC and buyout funds had almost doubled, as compared with the 1980–1998 period, and continued to increase during the bubble (especially VC funds). During the post-bubble period, the number of funds established again declined significantly, but not as much as the number of funds established in the 1980s and early 1990s. Since the financial crises, only a few new VC and buyout funds have been raised, possibly because of unfavorable exit markets and lack of capital supply from capital-constrained institutional investors.

[Please insert Figure 1 about here]

Table 1 reports for our sample the distribution of VC and buyout deals by investment year from 1980 through 2009. The sample is divided into buyout and VC funds and by US and

non-US funds. The table shows that in the early 1980s, the number of deals was lower than that in the 1990s and 2000s. This is true for the buyout and VC deals and for deals done by US and non-US funds. For the US buyout, the number of deals realized was higher in the 1980s and 1990s than those in the 2000s. The pattern is consistent for non-US buyout funds. For the VC funds, there were more realized deals in the 1980s and 1990s than in the 2000s in terms of numbers and proportions, consistent with the need for a longer investment period of several years in VC before an exit is possible. These results are not limited to US VC funds, but also non-US VC funds. Although the number of investments has increased in the 2000s, the rate of realized deals has decreased proportionally as compared with 1980s and 1990s. As Table 1 shows, VC deals are more than twice the number of buyout deals, while for the US subsample, the VC deals are approximately three times the number of buyout deals.

[Please insert Table 1 about here]

2.2. Definition of Risk Measures

To analyze whether differences in risk explain performance persistence, we construct several measures of risk for our sample of private equity funds. The first measure of risk is the *Intra-Fund Volatility of IRRs*. For a fund that has invested in N portfolio companies with returns, as measured by the IRR, given by IRR_1, IRR_2, …, IRR_N, this risk measure is calculated by

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(IRR_i - IRR)^2},$$

where IRR is the mean rate of return of all the N investments made by the fund. This measure corresponds to the standard deviation of IRRs of individual investments made by the fund. It proxies for the variability or dispersion of the investment returns of a fund around the mean value. Thus, funds that take on high levels of investment risk, on average, display higher levels of intra-fund volatility than funds that take on low levels of risk.

The intra-fund volatility presented previously is only a valid measure of risk a fund takes when returns are adequately captured by a normal distribution. The reason is that the intra-fund volatility does not distinguish between variations below and above the mean. To account for the fact that private equity returns are typically highly skewed, we use two additional measures: intra-fund downside and upside volatility are modified versions of the intra-fund volatility introduced previously that allow distinguishing between the different degrees of upside and downside variations in returns. The formal definition of *Intra-Fund Downside Volatility of IRRs* is

$$\sigma_D = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\min(IRR_i - Tar;0)^2} \ .$$

The formal definition of the *Intra-Fund Upside Volatility of IRRs* is

$$\sigma_U = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\max(IRR_i - Tar;0)^2} \ .$$

In both equations, "Tar" denotes the return target. We use a target return of zero in all the following calculations.

2.3. Summary Statistics of Sample

Table 2 reports the descriptive statistics of different risk measures for the full sample, buyout and VC deals. We also report statistics for two related measures of return distribution: Loss Rate and Intra-Fund Skewness of IRRs. Loss Rate refers to the percentage of investments that lead to complete loss and thus generate an IRR of –100%.

The mean (median) loss rate is 8.46% (3.85%) for the full sample (all quartiles combined), while for buyout and VC separately, these values are 6.06% (0.00%) and 14.82% (13.04%), respectively. As expected, the probability of total loss is greater for VC and buyout. The intra-fund volatility is high for the full sample with mean (median) of 101.22% (58.18%), while the value for buyout is 92.20% (57.99%) and for VC is 123.1% (69.76%). As indicated by the next two measures, the high intra-fund volatility is driven by the upside rather than the downside volatility. This observation is true for the buyout and VC deals. For example, the intra-fund downside volatility is 27.50% for the full sample compared with 97.21% for the intra-fund upside volatility. For the buyout, the downside volatility is 22.38% compared with 94.00% for the upside volatility. Similarly, for the VC, the downside volatility is 40.21% and the upside is 111.15%. The funds are positively skewed, especially for the VC funds, with a skewness of 1.62, compared with 0.89 for the buyout and 1.12 for the full sample.

The mean loss rate is high for the first quartile and low for the fourth quartile. However, the mean of intra-fund volatility for the first quartile is lower than the fourth quartile and consistent for the full sample, buyout and VC deals. We observe the same for the upside volatility, while for the downside volatility, the mean is high for the first quartile and low for the fourth quartile. In terms of skewness, the intra-funds IRR are highly skewed in the fourth quartile and less skewed in the first quartile. This is consistent for the full sample, buyout and

VC funds. The excessive skewness of the intra-fund IRRs justifies our choice of using robust regressions in our multivariate analysis.

[Please insert Table 2 about here]

3. ANALYSIS

3.1. Performance of VC and Buyout Investments

We measure the performance of VC and buyout investments using IRR and investment multiple. These measures of performance are widely used in the literature (see Harris et al., 2014). Our measure of IRR is gross of fees, which include carried interest. We use all realized deals of a fund to estimate the IRR using cash flow from initial investments to the exit. The investment multiple compares the sum of all investments in portfolios companies with the sum of all cash outflows and the residual value of the investments, similar to Harris et al. (2014). Table 3 shows the mean and median IRR and multiple in each investment year, based on deal-level data. The table further reports averages for the 1980s, 1990s and 2000s. The results are reported separately for buyout and VC funds. The table shows significant variations in the IRR and multiple for buyout deals across investment years. For all years, the average IRR is 19.8% and multiple is 2.644. Buyout deals before the financial crisis seem to have negative IRR and low multiple on average. The average IRR was low in the 1980s but significantly higher in the 1990s and 2000s. However, for the multiple the mean is quantitatively similar across all the investment years (mean multiple for 1980–2008 is 2.644).

[Please insert Table 3 about here]

For the VC funds, the performance patterns are different from buyout investments. The average IRR across all investment years is 23.6%, and multiple is 2.703. VC funds had exceptionally high IRRs of more than 70% on average during 1998 and 1999. This could be due to the dot.com bubble during that period. Over the same period, buyout funds generated an average IRR of 5.2% in 1998 and –5.6% in 1999. The average IRR was low in the 1980s, rather high in the 1990s, and again negative in the 2000s. Furthermore, the average investment multiple is lower in the 2000s than in the 1980s and 1990s.

Table 3 shows the IRRs and multiples for US and non-US funds, and Table 4 reports statistics of IRRs and investment multiples for the US funds only. We again separate the sample by fund type. For buyout funds, the average IRR in the 1980s was 16.9% compared with 26.2% in the 1990s and 14.4% in the 2000s. The corresponding median IRR was 20.3%, 23.0% and 19.7%, respectively. The fact that the median IRRs are higher than the means suggests that the IRRs are skewed to the left. The returns during the Internet bubble are negative, but after the bubble, the returns are positive. In addition, the multiples were high in the 1980s and 1990s but low in the 2000s. For VC deals, the average IRR is 24.3%, while in the 1990s, it was approximately 57.5% compared with –23.6%. During the dot.com bubble in 1999, VC funds significantly outperformed the buyout funds. However, post-2000 the VC returns have been low and have persisted until the end of 2009. The fact that VC returns have been low on average is consistent with Harris et al. (2014) findings. Taken together, our results show that IRRs for the

buyout segment are higher than those for VC after 2000, while in the 1990s, the IRRs of VC deals were higher than those of buyout deals. This evidence is consistent in the US and non-US subsamples.

[Please insert Table 4 about here]

3.2. Performance Persistence

In this section, we examine whether there is persistence in fund performance. The first step enables us to confirm existing findings. In the second step, we investigate whether fund risk explains the relationship between previous and current fund performance (i.e., performance persistence).

We examine the performance persistence using PME.[2] We measure PME using the approach adopted by Kaplan and Schoar (2005) and Harris et al. (2014), which compares an investment in a private equity fund with an equivalent investment in the relevant public stock market index. The PME can be viewed as a market-adjusted multiple of invested capital. For example, a PME of 1.5 indicates that at the end of the fund's life, investors ended up with 50% more than they would have obtained if they had invested in the public market. We use the S&P 500 Index to proxy for the public market for US funds and main national indices for all non-US funds. In accordance with the literature, we examine performance persistence for buyout and VC separately.

[2] Using IRR yields similar results. Results are available on request.

Table 5 shows our multivariate results for buyout funds, based on different subsamples: all buyout funds (Panel A), US buyout funds (Panel B) and non-US buyout funds (Panel C). Model 1a (Panel A) shows persistence in PME over time, and it is statistically significant at the 5% level. When we control for fund size (Model 2a), persistence in PME remains significant, though at the 10% level. Given that fund volatility may influence PME, in Models 3a and 4a we examine whether performance persistence remains significant after controlling for inter-fund volatility, our measure of risk. Thus, these two regressions directly test our prediction on performance persistence. As expected, persistence in PME is largely explained by fund volatility. In Model 4a, we split the inter-fund volatility into upside and downside volatility. We find that performance persistence is explained away by both upside and downside volatilities. In other words, the PME is positively related to the upside volatility and negatively related to the downside volatility. The different sign of coefficients is consistent with the definition of upside and downside volatility used in our analysis. Performance persistence is therefore related to both fund upside and downside volatility.

[Please insert Table 5 about here]

To investigate whether PME persistence is specific to the US (and thus connects our analysis with existing studies that focus on the US), we examine performance persistence for US funds only (Table 5, Panel B). The results shows that PME is persistent for US funds (Model 1b); this finding holds even when we control for fund size (Model 2b). Nonetheless, performance persistence is explained away by the inter-fund volatility, as shown in Models 3b. Model 4b

shows that the persistence in PME is again explained away by both upside and downside volatility. Finally, Panel C shows the results for non-US funds. The results from Models 1c to 4c show no persistence in the PME in general, but the impact of volatility and the split between upside and down side volatilities are important determinants of the PME. The effects of upside and downside volatilities on PME are again statistically significant.

We next investigate performance persistence for VC funds. Typically, VC deals are smaller than buyout deals, and it is possible that the persistence in PME is restricted to buyout investments. In addition, VC investment opportunities are likely to be more time varying because opportunities arise from technological changes. Thus, expertise may not be as long-lived as for buyouts, making performance persistence less likely. Table 6 replicates Table 5 but for VC funds. Panel A shows results for all VC funds, Panel B for US VC funds and Panel C for non-US VC funds. Similar to buyout funds, the results show that PME is persistent among VC funds even after we control for fund size (Models 1a and 2a). Furthermore, intra-fund volatility (Model 3a) and upside or downside volatilities (Model 4a) are related to performance but do not explain away performance persistence. This finding contrasts with the case of buyout funds in Table 5. The results of Panel A show that performance is persistent among the VC funds. Panels B and C indicate that PME is persistent for US VC funds, but not for VC funds located elsewhere. A reason for this might be the lack of development of VC markets outside the US, so expertise, an important ingredient of performance persistence (Korteweg and Sorensen, 2014), is lower. Moreover, inter-fund volatility explains away only a small fraction of performance persistence. The results remain qualitatively the same when we separate the inter-fund volatility into upside and downside volatilities. Thus, PME performance is persistent for VC

funds in the US. We find no evidence of PME performance persistence for non-US VC funds, though the PME is influenced positively by the upside volatility and negatively by the downside volatility in both subsamples. Overall, the results show that PME performance is persistent for the VC funds especially the US VC, in contrast with the buyout funds, for which the performance persistence is explained away by the upside and downside fund volatilities.

[Please insert Table 6 about here]

3.3. Risk Persistence

The findings in Section 3.2 raise follow-up questions about persistence in risk itself. In other words, if risk helps explain performance and affects the impact of performance persistence, it is likely that funds exhibit persistence in risk over time. We expect this to hold especially for US funds, for which performance persistence is strongest. To examine this prediction empirically, we estimate the same regressions as for performance persistence but now use our risk measure. Thus, we regress intra-fund volatility (standard deviation of IRRs) on the lag of intra-fund volatility using the same set of control variables and fixed effects as for performance persistence.

Table 7 reports the results on risk persistence. Panel A shows the results for buyout funds, and Panel B shows the results for VC funds. For buyout funds (Panel A), we find that risk is persistent. This result is statistically significant at all conventional levels, even after we control for fund size (Model 2). When separating the sample by US and non-US buyout funds, we find that the risk is persistent for US buyout funds (Models 3 and 4) but not for non-US funds. The

lack of significant findings for non-US funds is consistent with the lack of findings of performance persistence for non-US funds. For VC funds (Panel B), we find similar results to buyout, as we observe risk persistence, but it is mostly driven by US funds. For non-US VC funds, we find no risk persistence after controlling for fund size (Model 6). Therefore, fund size captures the effect of the previous fund's risk. Larger funds also appear to have lower risk than smaller funds.

Overall, our results show that risk is persistent in buyout and VC funds. Nonetheless, the persistence in risk is limited to US funds, while non-US funds show persistence only for the VC funds, which is explained away by fund size. These results suggest that performance persistence in VC or buyout funds, as documented in the literature, is due to risk persistence.

[Please insert Table 7 about here]

As mentioned previously, risk persistence could be due to upside or downside volatility, or both. Thus, in Tables 8 and 9 we examine risk persistence in upside and downside intra-fund volatility separately. In both tables, Panel A shows the results for buyout funds and Panel B for VC funds. We further separate samples by US and non-US funds. Model 1 of Panel A shows that downside volatility is persistent for buyout funds after we control for fund size. However, for the US buyout funds, we do not find evidence of downside volatility, while for non-US funds, the downside volatility is persistent even after we control for fund size (Models 5 and 6). In Panel B, we investigate risk persistence for VC funds. Models 1 and 2 show risk persistence in VC funds for the full sample. However, US funds exhibit higher persistence in the VC funds than non-US

funds (Models 3 and 4 as compared with Models 5 and 6). This difference is consistent with the view that the risk appetite for the US funds is different between VC and buyout. It is also true that VC funds take on more risk than buyout funds because of their deals, which are typically riskier than buyout investments. Moreover, the difference between US and non-US buyout funds suggests that the US market is more competitive, which may explain the lack of persistence in the first place. Indeed, in a more competitive market, managers with loss-making funds may not be able to stay in the market in the first place, so persistence is not observed.

[Please insert Table 8 about here]

We also examine whether the risk persistence is due to upside volatility. Table 9 reports the results. Panel A shows that upside volatility is not persistent in buyout investments. Separating the buyout funds into US and non-US samples, we find that only US funds show persistence in the upside volatility (Models 3 and 4 as compared with Models 5 and 6). For the VC funds (Panel B), we find no persistence in the upside volatility for VC funds in the full sample. However, non-US funds show persistence in the upside volatility (Model 5). In Model 6, we control for fund size, and the results show that risk persistence in the upside volatility is explained away by fund size. Thus, fund size drives persistence in the upside volatility for the non-US VC funds. Overall, these results suggest that there is no persistence in upside risk in any of the subsamples based on asset class (buyout or VC) or geography, with the sole exception of US VC funds. As previously, this result may be because the US VC market is more mature and

thus populated by more experienced fund managers who have the skills to select top-performing companies more often over time.

[Please insert Table 9 about here]

The Sharpe and Sortino ratios are alternative measures of risk (or risk-adjusted performance measures). In Table 10, we examine the persistence of these risk measures for all buyout funds, US funds and non-US funds. Model 1a (Panel A) shows persistence in the Sharpe ratio for all funds even after we control for fund size (Model 2a). Models 3a and 3b in Panel A show no evidence of risk persistence using the Sortino ratio. For the US funds (Panel B), we find no evidence of persistence using the Sharpe ratio; however, we find weak evidence (significant at 10%) of persistence using the Sortino ratio. For the non-US funds, we find strong evidence of persistence using the Sharpe ratio but again no evidence using the Sortino ratio (Panel C). The Sharpe ratio exhibits persistence because of the non-US funds, while the US funds do not exhibit any persistence based on the Sharpe or Sortino ratio.

[Please insert Table 10 about here]

Table 11 reports persistence results for the VC funds again using the Sharpe and Sortino ratios. Panel A shows the results for all VC funds, Panel B shows the results for the US funds and Panel C shows the results for non-US funds. Models 1a and 2a in Panel A show the results of the Sharpe ratio, and Models 3a and 4a show the results of the Sortino ratio. For all funds, we find

no evidence of persistence using either the Sharpe or Sortino ratio. Panel B shows the results for the US funds and clearly indicates that the Sortino ratio exhibits significant persistence, even after we control for fund size (Models 3b and 4b). Nonetheless, there is no evidence of persistence using the Sharpe ratio. For non-US VC funds, we find weak evidence of persistence using the Sortino ratio but not the Sharpe ratio. Overall, the results reveal that risk is persistent for the US and non-US funds when using the Sortino ratio but generally not the Sharpe ratio.

[Please insert Table 11 about here]

3.4. Is Performance Driven by Outperformers or Cost Minimization?

In this section, we investigate which type of risk helps explain outperformance, that is, whether performance is driven by picking outperformers (higher upside volatility) or minimizing losses (lower downside volatility). To do so, we focus on the IRR as a measure of performance. The IRR is the most appropriate measure here because we want to measure absolute returns, not risk-adjusted returns as done with PME.

In Table 12, we first examine the relationship between IRR and risk as measured by intra-fund volatility and then show the results for alternative measures of risk: skewness, downside volatility and upside volatility. These three measures help test for the direction of the distribution and, thus, the particular form of risk. The table presents results for all funds (separately for buyout and VC), US funds and non-US funds. For the full sample, we find that the IRR is positively related to intra-fund volatility (Model 1 for buyout and Model 4 for VC). The

coefficients are significant at the 1% level. In Models 2 and 5, we control for skewness and find that the results on volatility remain.

[Please insert Table 12 about here]

However, these results reveal that intra-fund volatility is not always a good proxy for fund risk. For example, for the US buyout funds, the coefficient on intra-fund volatility turns out to be non-significant. This is most likely because private equity returns tend to deviate significantly from a normal distribution, in which case the volatility does not adequately represent risk. Therefore, we also split the intra-fund volatility into downside and upside volatility in the regressions (see Models 3 and 6). As expected, we find that the IRR is negatively related to downside and positively related to upside volatility. The regression coefficients are highly significant (mostly at the 1% level), regardless of the sample and asset class, with the exception of non-US VC funds. It is worthwhile here to compare the absolute values of the coefficients to separate the effect of out- and underperforming investments on the fund IRR. The results show that in absolute terms, the coefficients for the downside volatility are much larger than the coefficients for the upside volatility. These differences in coefficients are highly significant, except for the non-US VC funds. That is, fund performance is driven more by fund managers being able to minimize losses than consistently choosing outperforming investments. This finding holds for both the buyout and the VC funds. However, in line with expectations, selecting outperforming deals typically has a stronger effect on the performance of VC funds

than for buyout funds, as indicated by the larger coefficients on the upside volatility for all funds and US VC funds only.

3.5. Additional Tests

We performed several robustness checks and additional tests. Our main finding on persistence in risk is also confirmed when treating Loss Rate (as defined in Section 2.3) as a measure of fund risk. Fund managers who have achieved a low loss rate in one fund will also largely have a lower loss rate in the next fund.

Other tests performed pertain to the question whether the relationship we find is due to other underlying relationships for which we did not control. For example, the relationship may be due to the strong specialization in private equity, especially in VC, in specific stages of development. That is, the consistently high loss rate across funds of a same manager could be due to this manager raising only early-stage funds, which tend to be riskier that other funds. However, adding dummies for stage focus of funds to the specification does not eliminate our result on risk persistence, nor does adding dummies for industry and regional focus of funds. These extra robustness checks confirm that risk persistence also holds within usual risk classifications (e.g., stage of development, geography, industry) of private equity funds. In this case, the underlying rationale for the persistence in risk could be due to the strong specialization need among fund managers. Another underlying factor that may generate persistence in risk is experience itself. To check for this possibility, we construct several measures of experience for the different funds in our sample and add them sequentially to our main specifications to check whether our conclusions about persistence in risk remain. We

could construct three separate proxies of experience: the fund's sequence number (i.e., whether the considered fund is the first, second, ... fund managed by the PE firm), the age of the PE firm (i.e., the vintage year of the last fund-raising minus the year in which the PE firm was founded), and the total number of portfolio companies of the PE firm (based on entire history in our sample). Unreported results confirm persistence in risk even after we control for management experience, suggesting that the relationship we capture is not driven by differences in experience.

4. CONCLUSION

This study examines the impact of fund-level risk on performance persistence as well as risk persistence in private equity. Consistent with Kaplan and Schoar (2005), we find that returns are persistent for VC and buyout funds for US funds. We further extend the analysis by providing evidence for non-US funds, for which persistence tends to be weaker. Our study extends the results of Kaplan and Schoar and related studies, by showing that risk as measured by the standard deviation of IRR is persistent for VC and buyout funds regardless of whether these funds are based in the US or outside the US. We interpret these results of performance persistence in private equity to be due largely to persistence in risk. In other words, private equity funds tend to invest persistently in deals with similar risk-return levels, which in turn leads to persistence in both risk and return.

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Figure 1: VC and buyout funds by vintage year

This figure shows the number of buyout and VC funds in our sample from 1980 to 2008.

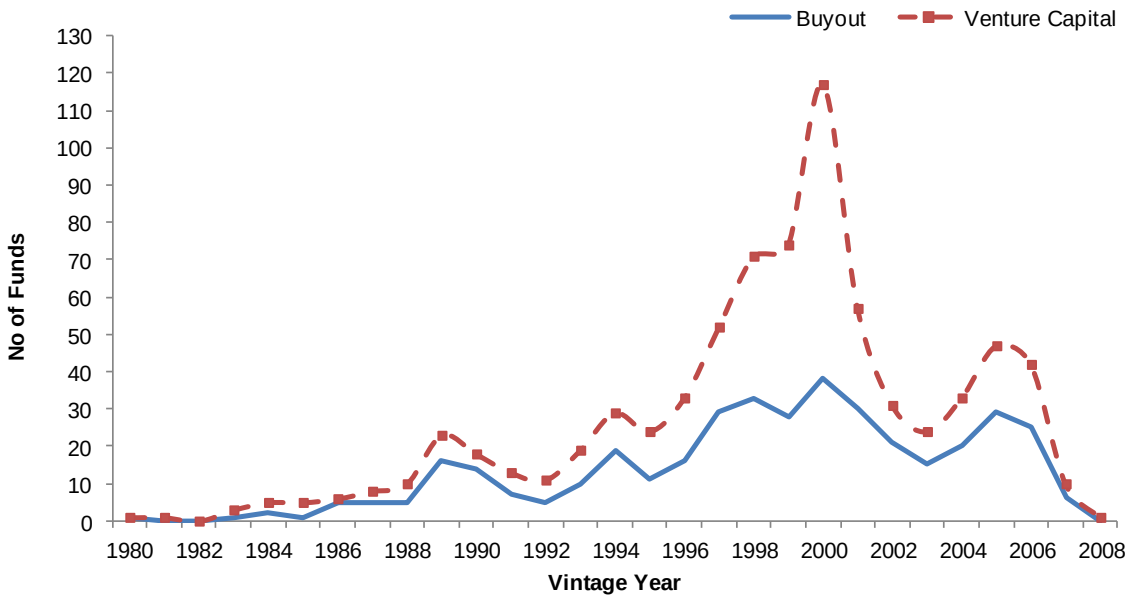

Table 1: **Sample distribution of VC and buyout investments**

This table shows the distribution of VC and buyout investments by investment year. The buyout and VC deals are divided into deals made by US and non-US funds. The table also indicates the number of these deals that are realized (i.e., exited). At the end, the table shows the total number of deals as well as the subsample of deals in the 1980s, 1990s and 2000s, respectively.

	Buyout investments					VC investments				
	Full sample	US		Non-US		Full sample	US		Non-US	
Investment year		All deals	Realized deals	All deals	Realized deals		All deals	Realized deals	All deals	Realized deals
1980	1	0	0	1	1	0	0	0	0	0
1981	5	0	0	5	5	8	8	7	0	0
1982	2	0	0	2	1	18	18	14	0	0
1983	5	1	1	4	4	19	19	16	0	0
1984	10	8	6	2	1	32	32	27	0	0
1985	17	12	9	5	5	48	48	47	0	0
1986	25	22	16	3	3	70	64	59	6	5
1987	56	28	23	28	24	73	51	44	22	19
1988	72	48	44	24	24	97	83	76	14	14
1989	97	73	72	24	24	130	122	118	8	7
1990	173	94	90	79	73	125	97	94	28	25
1991	178	85	83	93	89	143	95	79	48	43
1992	177	91	86	86	82	153	126	123	27	24
1993	182	106	101	76	70	219	154	142	65	60
1994	294	141	131	153	135	256	187	168	69	56
1995	271	113	97	158	141	314	236	212	78	64
1996	326	136	117	190	161	475	332	289	143	95
1997	400	144	111	256	208	584	440	354	144	92
1998	447	172	112	275	169	804	616	471	188	128
1999	539	192	117	347	218	1241	951	648	290	192
2000	702	249	132	453	244	1817	1253	715	564	292
2001	344	97	55	247	126	925	652	288	273	119
2002	366	113	46	253	132	680	514	177	166	46
2003	341	132	45	209	87	693	548	176	145	40
2004	385	155	36	230	53	773	603	138	170	41
2005	432	166	38	266	44	640	455	63	185	38
2006	438	156	7	282	25	614	467	35	147	6
2007	320	119	1	201	3	399	310	12	89	3
2008	91	38	1	53	0	178	152	2	26	1
2009	6	0	0	6	0	26	3	0	23	1
Total	**6702**	**2691**	**1577**	**4011**	**2152**	**11554**	**8636**	**4594**	**2918**	**1411**
1980s	290	192	171	98	92	495	445	408	50	45
1990s	2987	1274	1045	1713	1346	4314	3234	2580	1080	779
2000s	3425	1225	361	2200	714	6745	4957	1606	1788	587

Table 2: Summary statistics of different risk measures of funds

This table shows the mean and median values for Loss Rate, Intra-Fund Volatility of IRRs, Intra-Fund Downside and Upside Volatility of IRRs and Intra-Fund Skewness of IRRs, based on deal-level cash flow data. The table shows the statistics for the full sample, buyout and VC deals and for all quartiles, first quartile and fourth quartile, respectively.

		All quartiles			First quartiles			Fourth quartiles		
		Full sample	Buyout	VC	Full sample	Buyout	VC	Full sample	Buyout	VC
Loss Rate										
	Mean	8.46%	6.06%	14.82%	11.97%	8.57%	16.61%	9.04%	4.59%	16.33%
	Median	3.85%	0.00%	13.04%	7.02%	0.00%	14.73%	4.55%	0.00%	15.00%
Intra-Fund Volatility of IRRs										
	Mean	101.22%	92.20%	123.10%	60.94%	46.32%	78.46%	174.62%	144.47%	214.23%
	Median	58.18%	57.99%	69.76%	44.82%	42.29%	50.42%	107.81%	82.13%	150.58%
Intra-Fund Downside Volatility of IRRs										
	Mean	27.50%	22.38%	40.21%	35.72%	29.17%	44.01%	25.66%	14.79%	41.04%
	Median	27.96%	23.21%	43.25%	39.12%	31.99%	47.66%	25.87%	3.39%	44.95%
Intra-Fund Upside Volatility of IRRs										
	Mean	97.21%	94.00%	111.15%	43.59%	30.33%	57.58%	186.69%	167.17%	213.48%
	Median	50.18%	56.10%	55.49%	19.22%	17.38%	21.47%	114.28%	96.67%	145.98%
Intra-Fund Skewness of IRRs										
	Mean	1.12	0.89	1.62	0.59	0.48	1.07	1.75	0.96	1.95
	Median	0.94	0.82	1.49	0.13	0.08	0.39	1.71	1.20	2.44

Table 3: Summary statistics on deal-level performance

This table shows the mean and median IRR and investment multiple based on the full sample of fully realized deals. The table shows IRR and investment multiple statistics by investment year and by buyout and VC subsamples. IRR and multiples are gross of fees and carried interest payments.

	Buyout					VC				
		IRR		Multiple			IRR		Multiple	
Investment year	No. deals	Mean	Median	Mean	Median	No. deals	Mean	Median	Mean	Median
1980	1	0.044	0.044	1.384	1.384					
1981	5	0.194	0.092	7.474	1.958	7	-0.167	-0.545	1.510	0.135
1982	1	-0.212	-0.212	0.171	0.171	14	0.262	0.256	8.497	3.414
1983	5	0.152	0.056	2.358	1.558	16	-0.346	-0.640	3.365	0.049
1984	7	0.794	0.471	9.303	9.506	27	0.042	-0.030	3.334	0.782
1985	14	0.248	0.304	4.487	2.797	47	-0.161	0.016	2.402	1.166
1986	19	0.303	0.250	3.142	2.839	64	0.061	0.091	3.332	1.700
1987	47	0.029	0.066	2.741	1.413	63	0.003	0.073	2.465	1.272
1988	68	0.045	0.104	2.169	1.723	90	-0.067	0.004	3.279	1.022
1989	96	0.001	0.144	2.410	1.620	125	0.130	0.099	3.016	1.682
1990	163	0.197	0.171	2.946	2.000	119	0.093	0.101	2.609	1.655
1991	172	0.349	0.343	3.313	2.551	122	0.055	0.124	2.631	1.432
1992	168	0.369	0.268	3.138	2.133	147	0.273	0.130	4.174	1.652
1993	171	0.563	0.424	5.048	3.025	202	0.209	0.108	3.542	1.597
1994	266	0.320	0.300	3.128	2.338	224	0.225	0.101	4.122	1.404
1995	238	0.300	0.237	2.741	1.866	276	0.385	0.214	3.922	1.650
1996	278	0.208	0.163	2.825	1.694	384	0.387	0.108	4.436	1.391
1997	319	0.159	0.185	2.577	1.785	446	0.359	0.040	4.122	1.128
1998	281	0.052	0.123	2.128	1.608	599	1.166	-0.026	5.115	0.946
1999	335	-0.056	0.056	1.624	1.252	840	0.714	-0.451	2.092	0.205
2000	376	-0.138	-0.005	1.549	0.990	1007	-0.384	-0.611	0.646	0.067
2001	181	0.123	0.223	2.265	1.907	407	-0.368	-0.448	1.043	0.170
2002	178	0.358	0.393	3.189	2.390	223	0.105	-0.299	1.627	0.440
2003	132	0.565	0.569	3.020	2.731	216	0.015	-0.122	2.018	0.759
2004	89	0.512	0.590	2.680	2.633	179	0.202	-0.045	2.220	0.927
2005	82	0.447	0.551	2.141	1.808	101	0.010	-0.131	1.283	0.762
2006	32	0.564	0.677	2.032	2.025	41	0.263	-0.941	1.387	0.004
2007	4	-0.714	-0.999	0.310	0.023	15	0.929	-0.962	1.213	0.059
2008	1	-1.000	-1.000	0.000	0.000	3	-0.639	-1.000	0.347	0.000
Total	**3729**	**0.198**	**0.205**	**2.644**	**1.874**	**6004**	**0.236**	**-0.137**	**2.703**	**0.574**
1980s	263	0.079	0.135	2.836	1.732	453	0.011	0.063	3.150	1.284
1990s	2391	0.214	0.199	2.791	1.892	3359	0.555	0.003	3.671	1.015
2000s	1075	0.191	0.246	2.269	1.867	2193	-0.206	-0.518	1.129	0.144

Table 4: Summary statistics on deal-level performance for the US subsample

This table shows the mean and median IRR and investment multiple based on the US sample of fully realized deals. The table shows IRR and investment multiple statistics by investment year and by buyout and VC subsamples. IRR and multiples are gross of fees and carried interest payments.

Investment year	US buyout					US VC				
		IRR		Multiple			IRR		Multiple	
	No. deals	Mean	Median	Mean	Median	No. deals	Mean	Median	Mean	Median
1981	—	—	—	—	—	7	-0.167	-0.545	1.510	0.135
1982	—	—	—	—	—	14	0.262	0.256	8.497	3.414
1983	1	0.381	0.381	3.635	3.635	16	-0.346	-0.640	3.365	0.049
1984	6	0.922	0.660	10.654	12.275	27	0.042	-0.030	3.334	0.782
1985	9	0.648	0.536	6.386	2.976	47	-0.161	0.016	2.402	1.166
1986	16	0.323	0.354	3.449	2.994	59	0.067	0.092	3.469	1.710
1987	23	0.213	0.110	3.572	1.530	44	-0.031	0.049	2.576	1.242
1988	44	0.087	0.150	2.336	2.011	76	-0.072	0.004	3.550	1.019
1989	72	0.046	0.161	2.702	2.102	118	0.131	0.098	3.073	1.679
1990	90	0.385	0.309	3.610	2.095	94	0.140	0.175	2.777	1.820
1991	83	0.501	0.483	3.931	2.899	79	0.042	0.124	2.793	1.432
1992	86	0.378	0.286	2.820	2.133	123	0.154	0.109	4.014	1.651
1993	101	0.669	0.439	6.199	3.917	142	0.221	0.136	3.552	1.613
1994	131	0.318	0.326	3.411	2.569	168	0.223	0.102	3.613	1.463
1995	97	0.341	0.211	2.854	1.701	212	0.437	0.217	4.224	1.650
1996	117	0.194	0.117	2.689	1.639	289	0.486	0.120	4.928	1.725
1997	111	0.117	0.188	2.890	1.865	354	0.308	0.000	4.302	1.000
1998	112	0.037	0.124	1.941	1.715	471	1.234	-0.063	5.525	0.776
1999	117	-0.141	0.004	1.355	1.027	648	0.703	-0.501	1.950	0.164
2000	132	-0.221	-0.124	1.118	0.586	715	-0.425	-0.616	0.648	0.067
2001	55	0.056	0.216	1.984	1.753	288	-0.381	-0.513	1.070	0.108
2002	46	0.488	0.498	4.182	2.826	177	0.077	-0.274	1.785	0.540
2003	45	0.536	0.547	2.599	2.438	176	-0.037	-0.255	1.574	0.621
2004	36	0.556	0.590	2.700	2.382	138	0.206	-0.023	2.167	0.947
2005	38	0.277	0.386	1.827	1.273	63	0.006	-0.540	1.309	0.200
2006	7	0.396	0.311	1.724	1.552	35	0.231	-1.000	1.207	0.000
2007	1	-1.000	-1.000	0.000	0.000	12	0.042	-0.976	0.885	0.045
2008	1	-1.000	-1.000	0.000	0.000	2	-0.458	-0.458	0.521	0.521
Total	**1577**	**0.225**	**0.224**	**2.891**	**1.932**	**4594**	**0.243**	**-0.159**	**2.815**	**0.523**
1980s	171	0.169	0.203	3.273	2.193	408	0.008	0.060	3.276	1.266
1990s	1045	0.262	0.230	3.115	2.067	2580	0.575	0.000	3.797	1.000
2000s	361	0.144	0.197	2.063	1.492	1606	-0.231	-0.540	1.121	0.132

Table 5: Performance persistence in buyout funds

This table shows performance persistence for buyout funds based on the sample of all funds, US funds and non-US funds. The dependent variable is the logarithm of PME of the current fund (at time t). PME $_{t-1}$ is the logarithm of PME of the previous fund, whose coefficient tests for persistence in performance. *Fund Size* is measured as the logarithm of the fund's total invested capital. *Intra-F Vol, Upside Vol and Downside Vol* are intra-fund volatility, upside volatility and downside volatility, respectively. The volatility measures are estimated using deal-level data, as defined in Section 2.2. *Diff. Coeff.* gives the difference (in absolute terms) of the coefficients for *Upside Vol* and *Downside Vol.*, while *t-Value Diff.* reports the value of the corresponding t-test. We include dummies for vintage year of current fund and previous fund in all our regressions. ***,**,* are significant level at 1%, 5% and 10%, respectively.

	Panel A: All buyout funds				**Panel B: US buyout funds**				**Panel C: Non-US buyout funds**			
	Models				***Models***				***Models***			
	1a	***2a***	***3a***	***4a***	***1b***	***2b***	***3b***	***4b***	***1c***	***2c***	***3c***	***4c***
PME $_{t-1}$	0.113**	0.101*	0.095*	0.074	0.171**	0.181**	0.105	0.109	0.087	0.085	0.098	0.004
	(2.08)	(1.85)	(1.77)	(1.47)	(2.18)	(2.27)	(1.43)	(1.59)	(1.15)	(1.11)	(1.40)	(0.06)
Fund Size		-0.031				0.009				-0.008		
		(-1.58)				(0.27)				(-0.29)		
Intra-F Vol			0.0537***				0.073**				0.070***	
			(2.76)				(2.11)				(3.03)	
Upside Vol				0.085***				0.116***				0.071***
				(4.81)				(3.78)				(3.28)
Downside Vol				-0.649***				-0.586***				-0.744***
				(-4.59)				(-3.45)				(-3.79)
No. Obs.	287	286	285	287	110	109	109	110	178	178	176	176
Adj. R-sq	0.038	0.049	0.092	0.199	0.487	0.458	0.593	0.677	0.260	0.230	0.215	0.177
Diff. Coeff.				0.564***				0.470***				0.673***
t-Value Diff.				(3.95)				(2.72)				(3.41)

Table 6: Performance persistence in VC funds

This table shows performance persistence for VC funds based on the sample of all funds, US funds and non-US funds. The dependent variable is the logarithm of PME of the current fund (at time t). PME $_{t-1}$ is the logarithm of PME of the previous fund, whose coefficient tests for persistence in performance. *Fund Size* is measured as the logarithm of the fund's total invested capital. *Intra-F Vol, Upside Vol and Downside Vol* are intra-fund volatility, upside volatility and downside volatility, respectively. The volatility measures are estimated using deal-level data, as defined in Section 2.2. *Diff. Coeff.* gives the difference (in absolute terms) of the coefficients for *Upside Vol* and *Downside Vol.*, while *t-Value Diff.* reports the value of the corresponding t-test. We include dummies for vintage year of current fund and previous fund in all our regressions. ***,**,* are significant level at 1%, 5% and 10%, respectively.

	Panel A: All VC funds				**Panel B: US VC funds**				**Panel C: Non-US VC funds**			
	Models				***Models***				***Models***			
	1a	***2a***	***3a***	***4a***	***1b***	***2b***	***3b***	***4b***	***1c***	***2c***	***3c***	***4c***
PME (t-1)	0.205***	0.214***	0.134**	0.124**	0.183***	0.189***	0.147**	0.137**	0.131	0.143	0.081	0.095
	(3.79)	(3.96)	(2.50)	(2.51)	(2.81)	(2.87)	(2.33)	(2.19)	(1.47)	(1.55)	(0.88)	(1.09)
Fund Size		0.031				0.022				-0.029		
		(0.96)				(0.52)				(-0.53)		
Intra-F Vol			0.088***				0.071***				0.273***	
			(3.76)				(2.78)				(3.56)	
Upside Vol				0.178***				0.082***				0.264***
				(8.61)				(3.43)				(3.93)
Downside Vol				-0.682***				-0.635***				-0.722*
				(-3.78)				(-2.88)				(-1.84)
No. Obs.	**246**	**248**	**247**	**247**	**191**	**191**	**190**	**191**	**55**	**54**	**56**	**54**
Adj. R-sq	0.389	0.388	0.417	0.553	0.426	0.416	0.46	0.486	0.43	0.42	0.46	0.48
Diff. Coeff.				0.504***				0.553**				0.458
t-Value Diff.				(2.77)				(2.49)				(1.15)

Table 7: Persistence in risk

This table shows risk persistence using intra-fund volatility estimated by deal-level data. Panel A shows the volatility persistence using buyout funds, and Panel B shows the persistence using VC funds. The dependent variable *Intra-F Vol* is the standard deviation of deal-level IRRs of the current fund (at time t), as defined in Section 2.2. *Intra-F Vol* $_{t-1}$ is the volatility of the previous fund. *Fund Size* is measured as the logarithm of the fund's total invested capital. We include dummies for vintage year of current fund and previous fund in our regressions. ***,**,* are significant level at 1%, 5% and 10%, respectively.

	All funds		**US funds**		**Non-US funds**	
Panel A: Buyout funds	*Models*					
	1	***2***	***3***	***4***	***5***	***6***
Intra-F Vol $_{t-1}$	0.157***	0.155***	0.249***	0.244***	0.079	0.078
	(3.43)	(3.36)	(5.07)	(4.58)	(1.12)	(1.08)
Fund Size		0.012		0.058*		0.012
		(0.48)		(1.67)		(0.28)
No. Obs.	**279**	**279**	**106**	**107**	**173**	**171**
Adj. R-sq	0.28	0.269	0.785	0.754	0.209	0.205
Panel B: VC funds						
Intra-F Vol $_{t-1}$	0.214***	0.218***	0.202***	0.160**	0.209***	0.005
	(3.40)	(3.45)	(2.76)	(2.24)	(3.3)	(0.01)
Fund Size		0.075		0.102*		-0.309***
		(1.64)		(1.76)		(-3.70)
No. Obs.	**241**	**241**	**186**	**184**	**54**	**51**
Adj. R-sq	0.434	0.441	0.668	0.5	0.827	0.81

Table 8: Persistence in downside risk

This table shows downside risk persistence using downside fund volatility estimated using deal data. Panel A shows the persistence using buyout funds, and Panel B shows the persistence using VC funds. The dependent variable *Downside Vol* is the downside volatility based on deal-level IRRs of the current fund (at time t), as defined in Section 2.2. *Downside Vol* $_{t-1}$ is the downside volatility of the previous fund. *Fund Size* is measured as the logarithm of the fund's total invested capital. We include dummies for vintage year of current fund and previous fund in our regressions. ***,**,* are significant level at 1%, 5% and 10%, respectively.

	All funds		**US funds**		**Non-US funds**	
Panel A: Buyout funds	*Models*					
	1	***2***	***3***	***4***	***5***	***6***
Downside Vol $_{t-1}$	0.367***	0.372***	0.077	0.101	0.433***	0.442***
	(5.95)	(5.99)	(0.67)	(0.89)	(5.76)	(5.89)
Fund Size		-0.003		-0.012		-0.017
		(-0.30)		(-0.61)		(-1.61)
No. Obs.	**288**	**288**	**110**	**110**	**178**	**178**
Adj. R-sq	0.33	0.328	0.391	0.4	0.322	0.337
Panel B: VC funds						
Downside Vol $_{t-1}$	0.596***	0.592***	0.607***	0.603***	0.145	0.878***
	(8.03)	(7.99)	(7.97)	(7.78)	(0.48)	(13.09)
Fund Size		0.012		0.002		0.002
		(1.12)		(0.18)		(0.30)
No. Obs.	**247**	**248**	**192**	**192**	**55**	**54**
Adj. R-sq	0.518	0.532	0.656	0.649	0.445	0.974

Table 9: Persistence in upside risk

This table shows upside risk persistence using upside fund volatility estimated using deal data. Panel A shows the persistence using buyout funds, and Panel B shows the persistence using VC funds. The dependent variable *Upside Vol* is the upside volatility based on deal-level IRRs of the current fund (at time t), as defined in Section 2.2. *Upside Vol* $_{t-1}$ is the upside volatility of the previous fund. *Fund Size* is measured as the logarithm of the fund's total invested capital. We include dummies for vintage year of current fund and previous fund in our regressions. ***,**,* are significant level at 1%, 5% and 10%, respectively.

	All funds		**US funds**		**Non-US funds**	
Panel A: Buyout funds			*Models*			
	1	***2***	***3***	***4***	***5***	***6***
Upside Vol $_{t-1}$	-0.006	-0.006	0.053	0.066**	-0.020	-0.019
	(-0.38)	(-0.38)	(1.57)	(2.14)	(-1.00)	(-0.96)
Fund Size		0.003		-0.069**		0.015
		(0.21)		(-2.35)		(0.69)
No. Obs.	**286**	**288**	**109**	**109**	**178**	**176**
Adj. R-sq	0.161	0.166	0.452	0.566	0.233	0.225
Panel B: VC funds						
Upside Vol $_{t-1}$	0.020	0.021	0.013	0.010	0.067***	-0.014
	(1.10)	(1.18)	(0.64)	(0.53)	(9.11)	(-0.55)
Fund Size		0.074*		0.090**		-0.211***
		(2.47)		(2.25)		(-5.56)
No. Obs.	**247**	**248**	**189**	**192**	**54**	**50**
Adj. R-sq	0.625	0.635	0.678	0.714	0.951	0.961

Table 10: Persistence in buyout funds using Sharpe and Sortino ratios

This table shows persistence in buyout funds using Sharpe and Sortino ratios estimated using deal data. The table shows the results for all buyout funds, US funds and non-US funds. The dependent variable is the Sharpe ratio in Models 1 and 2 and the Sortino ratio in Models 3 and 4. *Fund Size* is measured as the logarithm of the fund's total invested capital. We include dummies for vintage year of current fund and previous fund in our regressions. ***,**,* are significant level at 1%, 5% and 10%, respectively.

	Panel A: All buyout funds				**Panel B: US buyout funds**				**Panel C: Non-US buyout funds**			
	Models				***Models***				***Models***			
	1a	***2a***	***3a***	***4a***	***1b***	***2b***	***3b***	***4b***	***1c***	***2c***	***3c***	***4c***
Sharpe Ratio $_{t-1}$	0.127**	0.139**			0.055	0.055			0.216**	0.226***		
	(2.21)	(2.44)			(1.08)	(1.06)			(2.60)	(2.70)		
Fund Size		-0.029		0.049		0.001		0.067		-0.021		-0.007
		(-1.44)		(1.19)		(0.04)		(1.06)		(-0.77)		(-0.07)
Sortino Ratio $_{t-1}$			0.002	0.002			0.021	0.0247*			-0.009	-0.008
			(1.52)	(1.63)			(1.53)	(1.85)			(-0.02)	(-0.02)
No. Obs.	**279**	**280**	**201**	**202**	**107**	**107**	**82**	**83**	**172**	**171**	**116**	**117**
Adj. R-sq	0.103	0.119	0.851	0.853	0.714	0.708	0.926	0.929	0.174	0.148	0.807	0.835

Table 11: Persistence in VC funds using Sharpe and Sortino ratios

This table shows persistence in VC funds using Sharpe and Sortino ratios estimated using deal data. The table shows the results for all VC funds, US funds and non-US funds. The dependent variable is the Sharpe ratio in Models 1 and 2 and the Sortino ratio in Models 3 and 4. *Fund Size* is measured as the logarithm of the fund's total invested capital. We include dummies for vintage year of current fund and previous fund in our regressions. ***,**,* are significant level at 1%, 5% and 10% respectively.

	Panel A: All VC funds				**Panel B: US VC funds**				**Panel C: Non-US VC funds**			
	Models				***Models***				***Models***			
	1a	***2a***	***3a***	***4a***	***1b***	***2b***	***3b***	***4b***	***1c***	***2c***	***3c***	***4c***
Sharpe Ratio $_{t-1}$	0.076	0.078			0.024	0.014			0.206	0.218		
	(1.19)	(1.22)			(0.47)	(0.27)			(1.44)	(1.53)		
Fund Size		0.007		0.003		0.003		0.019		0.037		-0.015
		(0.34)		(0.06)		(0.14)		(0.35)		(0.72)		(-0.16)
Sortino Ratio$_{t-1}$			0.007	0.007			-0.0576***	-0.0577***			0.118*	0.113*
			(0.70)	(0.67)			(-6.47)	(-6.42)			(1.87)	(1.75)
No. Obs.	242	241	225	224	188	187	176	175	53	54	45	44
Adj. R-sq	0.468	0.411	0.663	0.64	0.568	0.548	0.766	0.764	0.300	0.315	0.574	0.549

Table 12: Impact of upside and downside risk on IRR

This table shows the relationship among IRR, intra-fund volatility, skewness, downside volatility and upside volatility. The table shows the results for all funds, US funds and non-US funds. The dependent variable is the IRR of funds. *Diff. Coeff.* gives the difference (in absolute terms) of the coefficients for *Upside Vol* and *Downside Vol.*, and *t-Value Diff.* reports the value of the corresponding t-test. We include dummies for vintage year of current fund and previous fund in our regressions. ***,**,* are significant level at 1%, 5% and 10% respectively.

	All funds						***US funds***						***Non-US funds***					
	Models						***Models***						***Models***					
	1	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*	*1*	*2*	*3*
	BO	BO	BO	VC	VC	VC	BO	BO	BO	VC	VC	VC	BO	BO	BO	VC	VC	VC
Intra-F. Vol_t	0.034***	0.026**		0.151***	0.157***		0.020	0.030		0.145***	0.152***		0.038***	0.022*		0.018	-0.009	
	(3.72)	(2.42)		(8.95)	(7.46)		(1.19)	(1.58)		(6.12)	(15.16)		(3.31)	(1.68)		(1.10)	(-0.40)	
Skewness		0.013			-0.005			-0.007			-0.004			0.031**			0.045**	
		(1.54)			(-0.64)			(-0.61)			(-0.45)			(2.54			(2.48)	
Down Vol_t			-0.359***			-0.227***			-0.268***			-0.360***			-0.343***			-0.165
			(-6.05)			(-3.23)			(-2.93)			(-4.55)			(-4.79)			(-1.12)
Up Vol_t			0.049***			0.149***			0.0335**			0.150***			0.264***			0.022
			(5.86)			(10.75)			(2.17)			(9.01)			(8.57)			(1.37)
No. Obs.	***389***	***383***	***392***	***376***	***370***	***375***	***148***	***147***	***149***	***272***	***269***	***273***	***241***	***236***	***242***	***102***	***100***	***100***
Adj. R-sq	0.279	0.274	0.38	0.659	0.654	0.682	0.485	0.477	0.512	0.706	0.708	0.772	0.263	0.279	0.809	0.436	0.392	0.422
Diff. Coeff.			0.310***			0.078			0.235**			0.210***			0.079			0.143
t-Value Diff.			(5.17)			(1.09)			(2.53)			(2.59)			(1.01)			(0.97)