How do hedge funds manage portfolio risk?*

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Abstract

We investigate the determinants and effectiveness of methods that hedge funds use to manage portfolio risk. We find that levered funds are more likely to use formal models to evaluate portfolio risk and funds with higher levels of proprietary capital are more likely to have dedicated risk officers and risk officers with no trading authority. Funds in our sample that use formal models performed significantly better in the extreme down months of 2008 and, in general, had lower exposures to systematic risk. Moreover, funds employing value at risk and stress testing had more accurate expectations of how they would perform in a short-term equity bear market. Overall, our results suggest that models of portfolio risk increase the accuracy of managers' expectations and assist managers in reducing exposures to both systematic and downside risk.

1 Introduction

We investigate the determinants and effectiveness of methods that hedge funds use to manage portfolio risk. Although there is a well developed normative academic literature on hedge fund risk management (for example, see Lo (2001), Jorion (2007), and Jorion (2008)), there are no broad

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empirical investigations of how hedge funds actually manage portfolio risk and the effectiveness of such practices.

To investigate hedge fund risk management practices, we use a proprietary database of due diligence reports prepared by The Hedge Fund Due Diligence Group at Analytical Research (HedgeFundDueDiligence.com). Institutional investors commissioned these reports to better understand fund operations and risk exposures in order to evaluate potential hedge fund investments. The reports provide extensive detail on fund characteristics, manager backgrounds, internal operations, and risk management practices. This dataset addresses a major impediment to the examination of risk management practices—a lack of cross-sectional data on internal organizational practices (for a discussion of this point, see Tufano (1996)).

Specifically, the reports identify whether the fund employs formal models of portfolio risk (value at risk, stress testing, and scenario analysis), whether the fund's risk officer is dedicated solely to risk management, whether the risk officer has trading authority, and whether the fund employs limits on the concentration of investment positions. The timing of these reports provides a natural experiment to examine the effectiveness of risk management practices. Namely, the reports were compiled prior to 2008, thereby allowing us to correlate previously implemented risk management practices with subsequent fund performance during the equity bear market of September through November 2008. In addition, for a subset of funds in our sample, the reports provide managers' expectations of how their funds would perform under extreme financial events such as a short-term equity bear market. These expectations were also elicited prior to 2008, thereby allowing us to compare expectations with actual fund performance in the equity bear market of late 2008.

We find significant heterogeneity in the methods that funds use to manage portfolio risk. Levered funds are more likely to use formal models of portfolio risk, funds that hold large numbers of positions are more likely to have dedicated risk officers and risk officers with no trading authority, and funds that hold positions for longer durations are less likely to have position limits. Moreover, we find that the likelihood that a fund has either a dedicated head of risk management or a risk officer with no trading authority increases in the fund's proprietary capital, implying that fund managers increase risk oversight when they have more personal wealth invested in their fund.

Stulz (1996) proposes that the goal of risk management is the "elimination of costly lower-tail outcomes." We therefore posit that if risk management practices are effective, then funds with more extensive risk management should perform better during extreme negative financial events. Consistent with our thesis, we find that funds that using formal models of portfolio risk did relatively better in the extreme down months of 2008. The magnitude of these effects are economically significant. Controlling for size, age, investment style, and portfolio characteristics, funds in our sample that use at least one model of portfolio risk had returns in October 2008 that were six percentage points higher than funds that did not use any type of model. Moreover, we find similar differences in performance when we limit the analysis to the most prevalent investment style, long-short equity. Consistent with risk models assisting only in extreme periods, we find no differences in performance between funds that do and do not use risk models in 2007 or in the first six months of 2009.

An alternative explanation for the results is that unobserved manager ability determines both the use of portfolio risk models and fund performance in the down months of 2008. To proxy for ability, we hand collected the educations of the management team. Although we find some evidence that technically able managers are more likely to use risk models, the associations between risk models and performance in the down months do not change when we control for ability.

Another alternative explanation is that funds select risk management practices based on their risk exposures. The weight of our evidence, however, points toward risk management practices assisting managers reduce downside. If self-selection based on risk exposures drives our results, then funds investing in riskier and more volatile assets presumably employ stronger risk management practices. In contrast, we find that the monthly returns of funds that use models have significantly *lower* volatilities. Moreover, examining the skewness of returns, we find that the October 2008 returns of funds that do not use models are more *negatively* skewed than the returns of funds that employ models of portfolio risk, suggesting that funds that do not use models face greater left tail risk and that differences in performance are not driven by a mean shift in returns. A third potential explanation is that differences in fund quality drive the association between risk models and fund performance in the down months of 2008. If differences in fund quality drive our results, then funds using models should consistently outperform their peers. Although funds that use formal models perform better during the short-term equity bear market of 2008, we find *no* significant differences in the performance of hedge funds with different risk management practices during 2007 and the first six months of 2009. A fourth alternative explanation is that the use of models is correlated with the fund's overall risk culture. We find, however, no associations between performance and the other risk management practices besides models, suggesting that the fund's overall risk culture does not drive our results.

In addition to downside risk, risk models are also associated with systematic risk exposures. Using returns reported over the 30 month period between January 2007 and June 2009, we find that funds using models had significantly lower exposures to systematic risk. These differences in systematic risk exposures are also economically significant. Controlling for investment style and portfolio characteristics, the betas of funds using at least one model are -0.350 lower than the betas of funds that do not use at least one model.

Finally, we posit that risk management practices improve the fund managers' understanding of how changes in the financial environment would affect their fund's performance. Examining performance during the equity bear market that occurred from September through November 2008, we find that managers of funds that use value at risk and stress testing appear to have more accurate expectations about how their fund would perform during a short term equity bear market. In contrast, we find no association between the accuracy of expectations and the other risk management practices. Overall, our results suggest that models of portfolio risk assist managers in reducing exposures to both downside and systematic risk and increase the accuracy of managers' expectations.

We contribute to the risk management literature by examining the voluntary adoption of risk management practices in an unregulated setting. Prior research focuses on a limited set of choices, such as the choice of hiring a chief risk officer or the hedging of commodity prices and/or interest rates, made by bank holding companies, regulated utilities, and other SEC registrants (for example, see Geczy, Minton, and Schrand (1997), Geczy, Minton, and Schrand (2007), and Ellul and Yerramilli (2010)). In contrast, our proprietary data set and empirical setting enable us to investigate a broader set of risk management practices in a domain for which there is minimal academic research on how organizations manage risk.

We further contribute by examining outcomes from risk management. Prior research on the benefits of risk management practices typically relies on either excess returns around the announcement of a chief risk officer (for example, Liebenberg and Hoyt (2003)) or on the association between hedging and firm value (for example, Guay and Kothari (2003) and Jin and Jorion (2006)). This prior research relies on correctly specifying a model of expected returns or market value. In contrast, our dataset provides risk management practices in place prior to the 2008 financial crisis, thereby allowing us to estimate the relation between predetermined risk management practices and subsequent performance during an extreme event.

We also contribute to the risk management literature by examining the accuracy of fund managers' expectations of future performance, and the extent to which risk management practices are associated with more accurate expectations. Outside of the management earnings forecast literature, there is minimal empirical evidence that compares manager's expectations of performance with *ex post* realizations, and no research on either hedge funds or organizational performance given changes in the economy (for a discussion, see Cassar and Gibson (2008)). In doing so, we provide evidence of a specific benefit of better risk management practices—namely, increasing the accuracy of expectations.

We also contribute to the literature on the internal operations of hedge funds. Due to a lack of data, there is minimal academic research on the internal structures and operations of hedge funds, especially on how they manage portfolio risk. Nevertheless, Jorion (2000) and Lo (2001) conjecture that, given the atypical nature of hedge funds, the risk management practices used in other financial services firms are not applicable. Furthermore, Lo (2001) conjectures that investors and managers of hedge funds historically devoted little attention to active risk management practices. Despite these conjectures, we find using a recent sample that many funds implement portfolio risk management practices and that these practices are associated with differences in the accuracy of expectations and in exposures to downside and systemic risk.

Finally, regulators of financial markets have an interest in the extent to which fund managers understand their exposures to financial risks. As discussed by Chan, Getmansky, Haas, and Lo (2007), the Senior Supervisors Senior Supervisors Group (2008), and Ellul and Yerramilli (2010), in light of the recent crisis, a primary concern of regulators is the extent to which inadequate risk management practices affect the stability of financial markets. Although there has been substantial growth in the hedge fund industry, there is limited research on how hedge funds manage portfolio risk and the extent to which such practices prevented or exacerbated investment choices that contributed to the recent financial crisis. Our results suggest that models of portfolio risk assisted managers in avoiding investments that performed poorly during the crisis.

2 Sample

To investigate hedge fund risk management practices, we use a proprietary database of due diligence reports prepared by HedgeFundDueDiligence.com.[1] Institutional investors commissioned these due diligence investigations to better understand fund operations and risks in order to evaluate potential hedge fund investments. Consequently, this sample represents a set of hedge funds that were actively seeking to capital.[2] The vendor obtained the information contained in these reports from several sources, including on-site visits and interviews with key staff, discussions with service providers, and reviews of offering memorandums. The reports provide an extensive array of detail regarding fund and manager characteristics, portfolio characteristics, contract terms, performance expectations, and risk management practices.

Our sample consists of 427 funds run by 358 unique managers investigated from 2003 to 2007. Table 1 provides descriptive statistics for our sample funds. The mean (median) fund has $305 million ($107 million) in assets under management and is, on average, less than three years old (1,020 days) at the time of due diligence. The majority of funds (84 percent) are located offshore and more than half (54 percent) use explicit leverage, as opposed implicit leverage arising from derivatives.

The due diligence reports provide details on the funds' portfolios that are not available in the commonly-used commercial databases of hedge fund returns. Namely, HedgeFundDueDiligence.com evaluated each fund's portfolio to determine the typical holding period of an investment position and the typical number of investment positions. In terms of typical holding period, 32 percent of the funds typically hold their positions for at least a year and 13 percent typically hold only for days. With respect to the number of positions, 41 percent of the funds typically hold between 1–39 investment positions at one time, while three percent hold typically thousands of positions.

To examine the effectiveness of the various hedge fund risk management practices, we merge these fund characteristics with monthly returns reported on the three major hedge fund returns commercial databases: Lipper TASS, Hedge Fund Research, and CISDM.[3] When funds report to

[1] Brown, Goetzmann, Liang, and Schwarz (2011), Cassar and Gerakos (2010), and Cassar and Gerakos (2011) also use this database.

[2] A potential concern with the database is that it consists only of funds willing to be subject to due diligence. According to the vendor, refusals of due diligence are, however, rare.

[3] For a discussion and comparison of these databases, see Agarwal, Daniel, and Naik (2011).

multiple databases, we obtain returns first from the Lipper TASS database and then from the Hedge Fund Research database. Of our sample funds, 114 have a full set of monthly reported returns over the period January 2007 through December 2008 on at least one of these three databases. Comparing the characteristics of the sample hedge funds that do and do not report to these three commercial databases reveals no significant statistical differences for any of the variables reported in Table 1.[4] Although compared to prior research on hedge funds this is a small sample, these 114 funds held over $48 billion in assets under management at the time of due diligence.

3 Risk management practices

We define portfolio risk management practices as procedures and mechanisms used to monitor and manage an organization's exposure to portfolio risk. Specifically, we are interested in the risks arising from the fund's investment portfolio as opposed to its operations.[5] We examine several indicators of overall risk management practices: the use of formal models to quantify and evaluate portfolio risk; the presence of a dedicated head of risk management; whether the head of risk management has trading authority; the use of limits on the concentration of investment positions.

Table 2 reports the descriptive statistics for these risk management practices. The due diligence firm's scope of investigation expanded during our sample period. Consequently, the number of non-missing responses varies across the risk management practices, with some responses only available for later observations. We report descriptive statistics both for the full sample used to estimate the determinants of various risk management practices and for the subset of funds that have reported monthly returns from January 2007 to December 2008. Univariate t-tests reveal no significant differences in the risk management practices between the full sample and the subsample with returns.

3.1 Models

The vendor queried sample funds about their use of formal models to evaluate portfolio risk:

[4] We note, however, that hedge funds that self-report returns to the commercial databases may not, therefore, be representative of the entire population of hedge funds (for a discussion of this point, see Agarwal, Fos, and Jiang (2010)). Another potential concern is funds subject to due diligence by the vendor differ from the general population of hedge funds (for a discussion of this point, see Brown et al. (2011)). The vendor is not, however, the only organization that carries out hedge fund due diligence. Due diligence is performed by other third-party providers, and in-house by fund-of-funds. Like other due diligence providers, HFDD clients are primarily major institutional investors and high net worth individuals who use their services on a repeated basis. Instead of undertaking due diligence, as discussed by Brown, Fraser, and Liang (2008a), investors can invest in funds of hedge funds that specialize in evaluating and monitoring fund managers.

[5] For research on hedge fund operational risk, see Brown, Goetzmann, Liang, and Schwarz (2008b).

value at risk, stress testing, and scenario analysis. As discussed by Jorion (2000), value at risk measures the maximum expected loss that can occur over a specified period at a specified quantile. Although value at risk is commonly used, Jorion (2010) points out it has several limitations that are problematic for hedge fund portfolios. First, value at risk assumes that the fund's portfolio is static, while funds typically follow dynamic trading strategies. Second, value at risk assumes that the fund is a price taker. But, if the fund is forced to liquidate a large position, prices could move adversely thereby leading to a larger loss than indicated by value at risk. Given these issues, funds often use two additional types of models that allow managers to examine the effects of extreme events. Stress testing identifies how the portfolio would respond to large shifts in relevant economic variables or risk parameters. Scenario analysis assesses how the portfolio would respond to severe but plausible scenarios, such as significant changes in interest rates or liquidity.

We find that 43.7 percent of funds employ value at risk, 52.1 percent use stress testing, and 46.4 percent use scenario analysis. Over half the sample (58.3 percent) employ at least one modeling approach and 36.4 percent of all funds employ all three modeling approaches. Given the correlations among use of the three types of models, for our empirical tests we create an indicator variable for whether the fund uses at least one model.

3.2 Head of risk management

The due diligence reports identify who is fund's head of risk management. They also indicate whether this person is dedicated to risk management, whether the head of risk management is part of the primary management team, and whether the head of risk management has trading authority. In our sample, 34.0 percent of funds have an executive dedicated to risk management. In the remaining 66.0 percent of funds, risk managers also undertook other investing or administrative functions. With respect to the extent of their trading authority, for 70.1 percent of the funds the head of risk management had full trading authority, while 4.2 percent had authority to invest only for hedging purposes. For the remaining 25.8 percent of the sample, the head of risk management had no trading authority.

3.3 Position limits

The due diligence reports also provide substantial detail regarding the use of investment position limits. For this practice, we focus only on the use of limits for asset classes in which the fund is actively investing. We find that 16.6 percent of our hedge funds have hard limits on the dollar amount or proportion of assets under management that they are allowed to hold in a specific position. We also find that 26.9 percent of funds, while not having hard limits, employ investment guidelines on the amount or proportion that can be invested in a given position. The remaining 56.4 percent of funds have neither hard limits nor guidelines for the concentration of their investment positions.

3.4 Measures of risk management practices

For our empirical tests, we code all dichotomous responses to yes/no questions as 1 for "yes" and 0 for "no." We further rank order variables if there is a natural ordering of risk management practices. For example, we code the trading authority of the head of risk management as follows: 0 for full trading authority; 1 for hedging authority; 2 for no trading authority. And, we code positions limits as follows: 0 for no limits; 1 for guidelines; 2 for hard limits. In robustness tests, we also code the risk manager's trading authority and the fund's position limits as nominal choices.

4 Determinants of risk management practices

Although hedge funds are mandated to take financial risks, funds typically attempt to limit their risk exposures only to the specific risks outlined in their offering documents. For example, some funds follow a market-neutral investment strategy, whereby managers attempt to minimize the fund's exposure to systematic risk. We posit that risk management practices assist managers in both monitoring and reducing their funds' exposures to risks that are not included in their mandate. Moreover, we posit that risk management practices assist managers in reducing exposures to downside risk.

Given these posited benefits, we predict that the demand for risk management practices is a function of fund characteristics including: leverage, fund size, the manager's wealth invested in the fund, and reputation. First, leverage increases the fund's exposure to changes in asset values. Moreover, large losses can lead to margin calls from lenders and investor redemptions, both of which can force the manager to quickly liquidate the portfolio at "fire sale" prices. Moreover, lenders may implicitly or explicitly require a minimum level of risk management. Therefore, ceteris paribus, levered funds can receive greater benefits from investments in risk management. We therefore predict a positive association between risk management investments and leverage. To measure leverage, we include an indicator for whether the fund uses explicit leverage.[6]

Second, the cost of implementing and operating risk management practices likely decreases in fund scale. For example, dedicated risk officers and formal models involve fixed costs. Therefore, we predict that risk management practices increase with fund size. Furthermore, size can capture quality, because better performing funds generally receive higher capital flows. Size can therefore also capture the extent that higher quality funds invest more in risk management. To measure size, we use the natural logarithm of investor assets.

Third, fund managers often invest a substantial proportion of their personal wealth in their fund. Given that managers are presumably risk averse, when undiversified managers have substantial wealth invested in their funds they likely have incentives to implement more extensive risk management practices to better understand and monitor risk exposures. Consequently, we predict a positive association between proprietary capital and risk management practices. To measure proprietary capital, we use the natural logarithm of proprietary assets, which represents personal investments in the fund made by the managers and employees.

Finally, managers of established funds possess valuable reputations. Therefore, they have more to lose, such as their ability to charge higher fees, start new funds, or keep existing investors, should substantial changes in the value of the funds invested assets occur due to unexpected risk exposures. Consequently, we posit that older funds have extensive risk management practices. Furthermore, fund age and risk management practices can be positively correlated if risk management increases the likelihood of fund survival. To proxy for reputation, we use the natural logarithm of the fund's age as of the date of the due diligence report.

To proxy for portfolio characteristics, we include in our empirical tests several variables taken directly from the due diligence reports. First, we include indicator variables for whether the portfolio is long or short biased. Second, we include indicator variables that capture the typical number of investment positions that the fund holds (1–39 Positions, 40–99 Positions, 100–199 Positions, 200–999 Positions, and 1000+ Positions) and the typical duration that the fund holds an investment position (Days, Weeks, Months, Quarters, and Years). These variables allow us to control for trading

[6] Because of differences in how the funds reported leverage levels (e.g., gross versus net leverage and typical versus maximum leverage, we use a simple indicator variable to capture whether the fund uses explicit leverage.

strategies that are likely correlated with risk management practices. For example, quantitative hedge funds typically hold thousands of positions for short periods and may be more likely to invest in risk management.

Table 3 reports Pearson correlations among the risk management practices and the fund and portfolio characteristics. Many of the risk management practices are positively correlated with each other. For example, the correlations among three types of models are all greater than 0.70, and their correlations with the head of risk management measures are all greater than 0.20. There are also significant univariate correlations between the risk management practices and the independent variables. Leverage is positively and significantly correlated with models, limits on the trading authority of the head of risk management, and position limits.

We next examine the determinants of portfolio risk models. Table 4 presents marginal effects from estimates of probit regressions that examine the determinants of portfolio risk model use. For all approaches examined, models are more likely to be employed in funds that use leverage, engage in a long bias investment strategy, and make investments over shorter duration. These effects are economically significant. For example, funds that use leverage are 17 percentage points more likely to use at least one model and funds whose portfolios are long biased are 21 percentage points more likely to use at least one model.

Table 5 presents estimates from a probit model and an ordered probit model that examine the determinants of whether the fund's risk officer is dedicated to risk management and whether the head of risk management has trading authority. Holding the amount of capital provided by outside investors constant, we find that funds with greater proprietary assets are more likely to have a dedicated head of risk management and less likely to give the head of risk management trading authority. Both findings are consistent with fund managers implementing more extensive risk management practices when they have greater personal wealth invested in their fund. In contrast, we find no such associations between risk officer characteristics and the capital provided by outside investors. In addition, younger funds and levered funds are less likely to give the trading authority to the head of risk management. Finally, funds that typically hold large numbers of investment positions are more likely to have dedicated head of risk management and less likely to give trading authority to the head of risk management.[7]

[7]We find similar results when we treat the risk officer's trading authority as a nominal choice and estimate the

Finally, in Table 6 we examine the determinants of limits on the concentration of investment positions. In this ordered probit regression we find that larger funds, older funds, and off-shore funds are more likely to have position limits in place. In addition, funds that hold many positions and funds that hold their positions for typically more than a week are less likely to implement position limits.[8]

5 Downside risk

Stulz (1996) proposes that the goal of risk management is the "elimination of costly lower-tail outcomes." We therefore next examine whether there are differences in relative performance in the extreme down months of 2008 based on the risk management practices outlined in Section 3. In untabulated analyses, we only find significant return relationships for formal risk models; none of the other practices are significantly associated with monthly performance in 2008. In what follows, we therefore report the relation between models and performance in the down months of 2008.

Tables 7 and 8 present univariate and multivariate comparisons of monthly performance in 2008 based on whether the fund uses risk models. In the multivariate tests, we include all of the independent variables used to model the determinants of risk management practices [Ln(Investor assets), Ln(Proprietary assets), Ln(Fund age), Leverage, Long bias, Short bias, Fund Offshore, Years, Quarters, Months, Weeks, 1000+ Positions, 200–999 Positions, 100–199 Positions, and 40–99 Positions] along with indicator variables for the fund's investment style. The style classifications are based on the Lipper TASS, the HFR, and the CISDM style designations and are presented in the Appendix. At the top of each table we present the month's return for the S&P 500 Index and the HFR Composite Index of hedge fund returns.

Consistent with models reducing downside risk, all of the coefficients on models are significantly positive in Table 8 for the months in 2008 in which the S&P 500 Index had a return of less than negative five percent.[9] The magnitude of the coefficients on models are economically significant. For example, the coefficient on value at risk for October 2008 is 6.417, implying that funds using value

determinants using multinomial logit.

[8] We find similar results when we treat investment limits as a nominal choice and estimate the determinants using multinomial logit.

[9] Even though the return on the S&P 500 Index was slightly positive and slightly negative for July and August, the coefficients on models are significantly positive for these two months. The positive and significant coefficients for July and August are, however, consistent with the fact that the return on the HFR Composite Index was negative for both months (July, −2.29 percent; August, −1.44 percent).

at risk had returns over 640 basis points higher than funds that do not use value at risk. Moreover, the univariate and multivariate results are similar in magnitude. For October 2008, the differences between funds using and not using models are as follows: value at risk, 6.417 (6.078) percentage points for the multivariate (univariate) test; stress testing, 6.041 (5.493) percentage points for the multivariate (univariate) test; scenario analysis, 7.686 (6.440) percentage points for the (univariate) multivariate test; at least one model, 5.999 (5.793) percentage points for the multivariate (univariate) test. We find similar comparisons between the univariate and multivariate estimates for the other months of 2008 in which the S&P 500 Index lost five or more percent. In addition, for the months in which the coefficients on models are statistically significant, the p values of the regressions decrease and the Adjusted R^2s increase.[10]

The lower downside risk of hedge funds using formal models could indicate overall differences in performance that are driven unobserved manager ability, which is correlated with risk management practices. To investigate this potential explanation, we examine whether models are associated with performance during 2007 and the first six months of 2009. As shown in Table 9, for these periods, we find no associations between models and performance for these periods, suggesting that models do not represent mean differences in performance but instead represent differences in exposures to downside risk.[11]

Although our tests include indicators for investment style, the typical holding period of an investment position, and the typical number of investment positions, our results could be driven by differences in style. To further control for investment style, we carry out several additional sets of analyses. First, in untabulated tests, we estimate the regressions presented in Table 8 but replace the dependent variable with a measure of the fund's abnormal return, which we measure as the difference between the fund's return and the return on the relevant HFR Style Index. The results for these tests are quantitatively and qualitatively similar to those presented in Table 8. Second, we re-estimate the regressions presented in Table 8 including each fund's beta estimated using monthly returns from 2004 through 2007. Once again, the results for these tests are quantitatively and qualitatively similar to those presented in Table 8. Third, we match funds that use models with funds that do not use models based on prior volatility and beta and then examine differences

[10] A potential concern is that the results are driven by outliers. To address this concern, we estimated median regressions and the unreported results are similar to those presented in Table 8.

[11] We find similar results when we examine differences in monthly performance over these periods.

in performance over September through November 2008. Once again, we find significantly better performance over these months for funds that use formal models.

Finally, we limit our sample to the largest investment style in our sample, namely long-short equity funds. Given that our sample of equity long-short funds is less than 30, we present univariate tests. In Table 10, we present univariate tests that compare the monthly performance in 2008 based on whether the long short fund uses models. For this subset of funds, we find significant differences in the down months of 2008 based on whether the funds uses models. Moreover, the magnitude of losses for funds not using models are similar to 16.94 percent loss experienced by the S&P 500 Index in that month: value of risk, −18.586 percent; stress testing, −16.574 percent; scenario analysis, −16.887 percent; at least one model, −16.635. In contrast, funds using models experienced significantly lower losses: value at risk, −2.114 percent; stress testing, −4.862 percent; scenario analysis, 2.626 percent; at least one model, −4.283 percent. Differences in performance are similar in the other down months of 2008. Furthermore, for this limited sample of long-short equity funds, we find no associations between risk management practices and performance in 2007 and in the first six months of 2009.

There are several alternative explanations for the results presented in this section. One potential explanation is that unobserved manager ability is correlated with both the use of models and fund performance in the down months of 2008. To control for unobserved ability, we hand collected data on the manager's education. Namely, for each member of the management team we collected their degrees (bachelors, masters, and Ph.D.) and whether their undergraduate and masters degrees were in technical subjects (math, science, or engineering) or in business or economics.[12]

Table 11 presents descriptive statistics for the managers in our sample. For the risk management team and the entire management team, we present the mean of the percentage with the relevant degree and the percentage of funds with at least one team member with such a degree. Over half the members of the risk and management teams have undergraduate degrees in either business or economics and over 40 percent have masters degrees in either business or economics. With respect to science or engineering degrees, they are slightly more prevalent for the risk management team (19 percent with undergraduate and 7 percent with masters) than for the entire management team

[12] Given the relatively small number of managers with Ph.D.s, we do not categorize doctorates by whether they are in technical subjects or in business or economics.

(14 percent with undergraduate and 4 percent with masters. Similar percentages have a Ph.D. (12 percent for the risk management team and 11 percent for the entire management team). We find similar but higher percentages when we examine whether at least one member of the team has the relevant degree.

Table 12 presents marginal effects from probit regressions that include as independent variables the percentages of the management team with each type of degree. Consistent with more technically able managers being more likely to use risk models, the coefficients on masters degrees in science or engineering are positive and statistically significant for value at risk and scenario analysis. In unreported analyses, we find similar results when we use the education of the risk management team and when we replace the percentage of the team with a degree with an indicator variable for whether at least one member of the team has the relevant degree.

Given that we find some evidence that our ability proxies are positively correlated with the use of risk models, we next examine whether ability, as proxied by education, is a correlated omitted variable in the performance regressions. Table 13 presents performance regressions that include as independent variables the percentages of the management team with each type of degree. For brevity, we present the results for whether the fund uses at least one type of portfolio risk model. In terms of sign, significance, and magnitude the coefficients on whether the fund uses at least one model are similar to those presented in Table 8. For example, the coefficient for October 2008 is 5.999 in Table 8 and 6.052 in Table 13. Moreover, we find similar results when use the individual types of models, the risk management team education measures, and indicator variables for whether at least one member of the team has the relevant degrees.[13] We therefore conclude that ability, at least as proxied by education, is not a correlated omitted variable.

A fund's use of models could proxy for a fund's overall investment in risk management. For example, the underlying risk culture at an institution could determine both the risk of the investments and the strength of the institution's risk management practices. As discussed by Ellul and Yerramilli (2010), if general risk culture drives our results, then there should be correlations between all of the risk management practices and performance. In fact, we find no such overall relationships. It therefore appears unlikely that these results are driven by such an omitted correlated variable.

[13] For managers who graduated from US undergraduate institutions, we also hand collected from US News and World Reports the first and third quartiles of the SAT scores for the incoming freshman class of 2003. The coefficients on risk models are unaffected by the inclusion of the SAT scores in the performance regressions.

Another potential explanation for our performance results is that riskier funds choose models. Several factors point against this selection-based explanation. First, as shown in Figure 1, the returns for funds that do not use models are more negatively skewed for October 2008, suggesting that riskier funds do not select models. In addition, as shown in Figure 2, the monthly return volatility over the period January 2007 through June 2009 is greater for funds that do not use models. These differences in volatility are statistically significant at the mean and median, and when we control for investment style and portfolio characteristics, further suggesting that this form of selection does not drive our results.

Selection, however, could be in the opposite direction. Namely, our results could be explained by less risky funds choosing models. But, models require investments of both managerial effort and financial resources. These presumably non-trivial costs raise the question of why less risky funds would be more likely to make such investments, given that the marginal benefit of such investments is likely lower for less risky funds.

An additional possibility is that the use of models is correlated with characteristics of the investment contract. For example, heterogeneity in fee structures or investor redemption rights might lead to heterogeneity in choices of risk management practices and/or exposures to downside risk. To investigate this possibility, in unreported tests we include the following variables in the performance regressions: the management fee, the performance fee, whether the fund has a lock up, whether the fund manager has the right to implement on gate on redemptions, and whether the fund has redemption fee. The associations between models and performance are robust to controlling for these measures.

The use of models could be negatively correlated with the extent to which a fund follows an investment strategy that is equivalent to writing out-of-the-money put options (or, euphemistically, provides "liquidity"). The large negative returns in the down months of 2008 for funds that do not use models are consistent with the performance of such strategies. To the extent that this explanation is descriptive of our results, we provide evidence on the incidence of such strategies and their performance in 2008.

A final possibility is that models are more likely to be used by quantitative hedge funds and that quantitative hedge fund performed better in the down months of 2008. We do not believe that quantitative hedge funds drive our results for several reasons. First, our empirical tests control for investment style along with the typical duration of an investment position and the typical number of investment positions. Second, to the extent that managers of quantitative hedge funds are more likely to have degrees in science and engineering, our results are robust to controlling for such degrees.

6 Systematic risk

As discussed by Asness, Krail, and Liew (2001), a major concern for investors is the extent to which a hedge fund has significant exposures to systematic risk. Namely, investors want to ensure that the fees (commonly, 2 percent as a management fee and 20 percent as a performance fee) do not reward managers for substantial exposures to systematic risk, which investors can obtain relatively cheaply in the futures or ETF markets. We therefore next examine whether models are associated with exposures to systematic risk.

Figure 3 compares the distributions of beta for funds that do and do not use formal models of portfolio risk. For each of the 112 funds with sufficient returns, we estimated its beta over the 30 month period starting January 2007 and ending June 2009 using the monthly return on the S&P 500 Index to proxy for the market return. For all three types of models, the mass of the distribution is higher for funds that do not use models. These differences are statistically significant at the mean and median. Moreover, for funds using models, the interquartile ranges include zero. In contrast, the interquartile ranges for funds not using models are all above zero.

Table 14 presents ordinary least squares estimates of differences in betas. For each model, we first present univariate differences and then multivariate differences that control for the fund's portfolio characteristics and investment style. In all of these specifications, betas are significantly lower for funds using models. In terms of economic significance, the betas of funds that use at least one model are -0.284 lower in the univariate test and -0.350 in the multivariate test. When we examine the subsample of equity long-short funds, we find similar results. Overall, these results show that funds using formal models have lower systematic risk exposures.

7 Accuracy of expectations

In this section, we examine the extent to which risk management practices are associated with the accuracy of manager expectations of how their fund will perform during periods of extreme financial events. We posit that risk management practices improve the fund managers' understanding of how their fund's performance is affected by changes in the financial environment. Moreover, increased accuracy of expectations in funds that undertake formal risk management could in part explain why some funds performed better during the short-term equity bear market of 2008.

During the due diligence process, the vendor queried managers about their expectation of their fund's performance during a short-term (one month) equity bear market, which are classified into five categories: -2 = "Down"; -1 = "Down (a little)"; 0 = "No effect"; 1 = "Up (a little)"; 2 = "Up."[14] The last due diligence report was completed in August 2007—over six months prior to the bailout of Bear Stearns and thereby allowing us to evaluate the accuracy of expectations prior to the crises of 2008.

Table 15 presents the distribution of managers' expectations and tabulates the expectations by the fund's risk management practices. As shown in the table, there are no systematic relations among the risk management practices and expectations. Moreover, Chi-square tests confirm that there are no statistically significant differences. We observe two interesting features of the hedge fund manager expectations. First, we observe substantial heterogeneity in the manager's expectations to how their fund would perform in a short-term equity bear market. For example, 27.5 percent (44.5 percent) of fund managers expect their fund performance to improve (worsen) during a one-month equity panic. Second, many (28 percent) hedge fund managers believe that their fund returns are neutral or not exposed to a sharp decline in financial equity markets.

To evaluate the accuracy of managers' expectations, we use the short-term equity bear market that occurred during the months of September, October, and November 2008. Over these months, the S&P 500 Index lost 9, 17, and 7 percent. We aggregate performance over these three months for two reasons. First, it is not clear that each month represents a separate short-term equity bear market. Second, prior research finds that hedge fund managers appear to spread negative returns over several months to smooth reported performance (for examples, see Bollen and Pool (2008) and Cassar and Gerakos (2011)).

Figure 4 plots mean and median performance over this period grouped by expected fund performance. If fund managers had accurate expectations of their fund's performance during a short-term

[14] Later in the sample period, HedgeFundDueDiligence.com increased the categories to include -3 "Down a lot" and $+3$ "Up a lot." We coded such responses as -2 and $+2$.

equity bear market, then we would observe the mean and median fund performance increasing in expected performance. In general, there is a minimal, at best, association between the manager's expectation and actual performance for the full sample.

We next examine whether models are associated with the accuracy of expectations. In Figures 5 through 7, we split the sample by the use of models. For each type of model, we compare both the mean and median performances conditional on the manager's expectation. Figure 5 shows that, in general, expectations are more accurate for funds that use value at risk to model portfolio risk. Figure 6 shows a slight relationship for stress testing. In contrast, as shown in Figure 7, there appears to be no relationship for funds that use scenario analysis. These findings suggest that value at risk, and to a lesser extent stress testing, are associated with more accurate manager expectations.

Next, we examine whether the other risk management practices associated with the accuracy of expectations. Consistent with our performance tests, we find no associations between manager accuracy and the other risk management practices. Overall, we conclude that increased accuracy is only associated with models.

8 Conclusion

We investigate the determinants and effectiveness of methods that hedge funds use to manage portfolio risk. By doing so, we provide the first broad empirical investigation of how hedge funds manage portfolio risk and overcome a major impediment to the examination of risk management practices—the lack of cross-sectional data on internal organizational practices.

We find that use of risk management practices are a function of fund characteristics, such as leverage, number of positions, and the capital invested by the fund managers. In addition, we find that funds that using formal models of portfolio risk did relatively better in the extreme down months of 2008. The magnitude of these effects are economically significant. Controlling for size, age, investment style, portfolio characteristics, and manager education, we find that funds in our sample that use at least one model of portfolio risk had returns in October 2008 that were six percentage points higher than funds that did not use any type of model. Moreover, we document that funds employing formal models to evaluate portfolio risk have more accurate expectations. Therefore, we provide evidence of a novel benefit of better risk management practices—namely, assisting managers in monitoring and better understanding the risks faced by their portfolio. Overall, our results suggest that models of portfolio risk, but not the other risk management practices, assist managers in reducing exposures to systematic and downside risks and increase the accuracy of manager's expectations.

Appendix: Style Classification

Style	Vendor Style	Vendor
Convertible Arbitrage	Convertible Arbitrage	CISDM
	Convertible Arbitrage	TASS
Emerging Markets	Emerging Markets	CISDM
	Emerging Markets	TASS
Equity Market Neutral	Equity Market Neutral	CISDM
	Market Neutral	CISDM
	Equity Market Neutral	TASS
Event Driven	Event Driven Multi-Strategy	CISDM
	Capital Structure Arbitrage	CISDM
	Merger Arbitrage	CISDM
	Option Arbitrage	CISDM
	Event Driven	HFR
	Event Driven	TASS
Fixed Income Arbitrage	Fixed Income	CISDM
	Fixed Income—MBS	CISDM
	Fixed Income Arbitrage	CISDM
	Fixed Income Arbitrage	TASS
Global Macro	Global Macro	CISDM
	Macro	HFR
	Global Macro	TASS
Long/Short Equity	Equity Long/Short	CISDM
	Equity Hedge	HFR
	Long/Short Equity Hedge	TASS
Multi-Strategy	Relative Value Multi-Strategy	CISDM
	Relative Value	HFR
	Multi-Strategy	TASS
Fund of Funds	Multi-Strategy	CISDM
	Fund of Funds	HFR
	Fund of Funds	TASS
Miscellaneous	Dedicated Short Bias	TASS
	Commodity Pool Operator	CISDM
	Managed Futures	TASS
	Equity Long Only	CISDM
	Regulation D	CISDM
	Sector	CISDM
	Single Strategy	CISDM
	Systematic	CISDM

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Figure 1: Distributions of returns for October 2008

This Figure compares the monthly distributions of returns for October 2008 for funds that use and do not use formal models of portfolio risk.

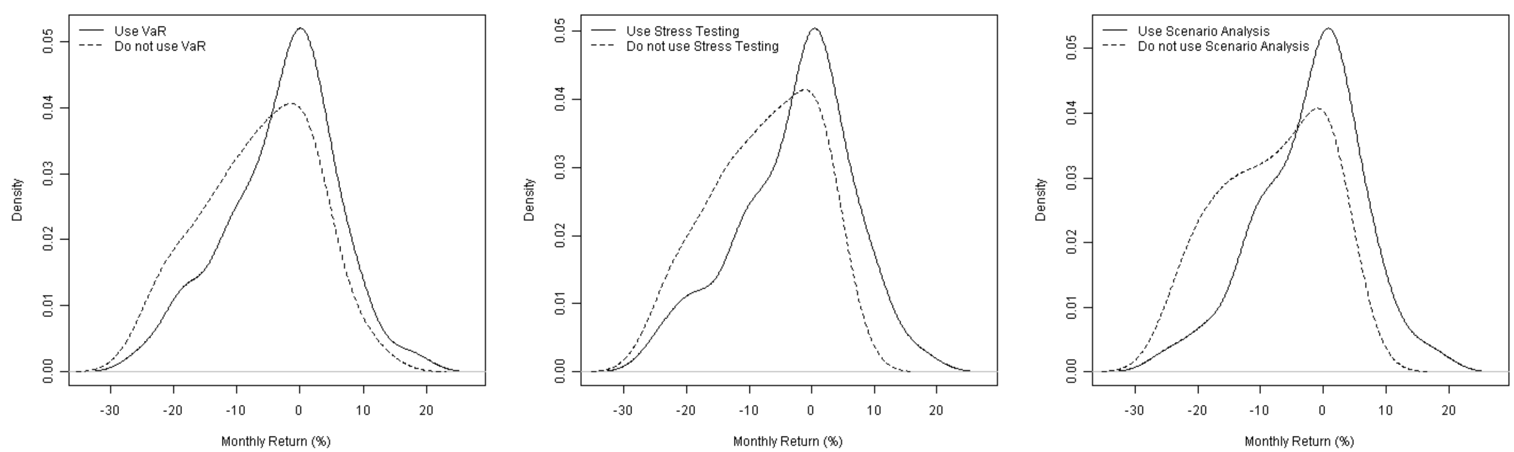

Figure 2: Annual volatilities by use of risk models

This Figure compares the distribution of annual volatilities for funds that use and do not use formal models of portfolio risk. Volatilities are estimated over the period January 2007 through June 2009 using the fund's monthly reported returns.

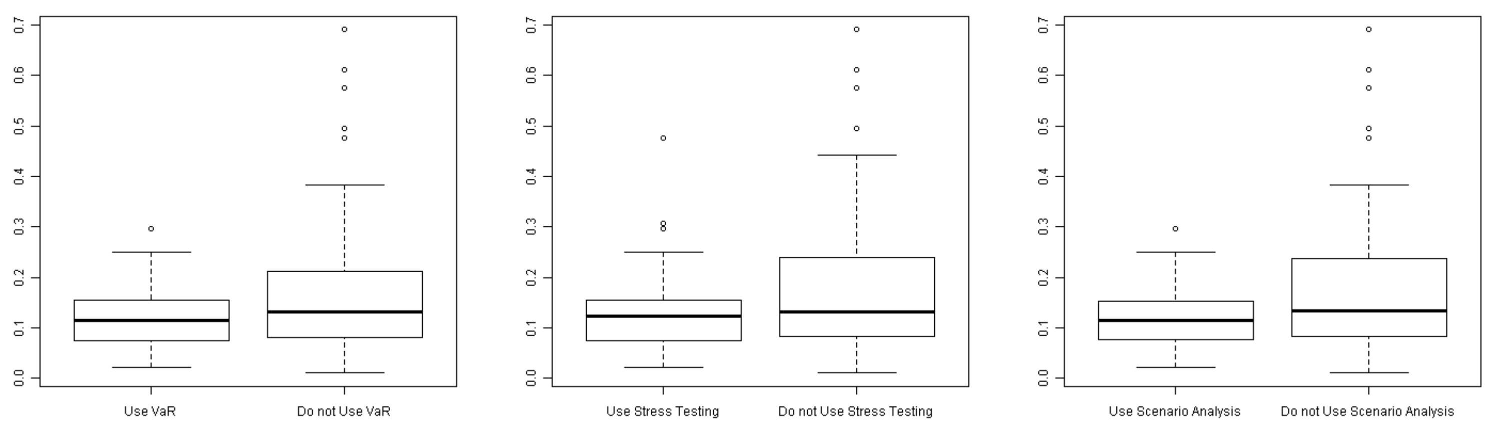

Figure 3: Betas by use of risk models

This Figure compares the distribution of betas for funds that use and do not use formal models of portfolio risk. Betas are estimated over the period January 2007 through June 2009 using the fund's monthly reported return and the monthly return on the S&P500 Index.

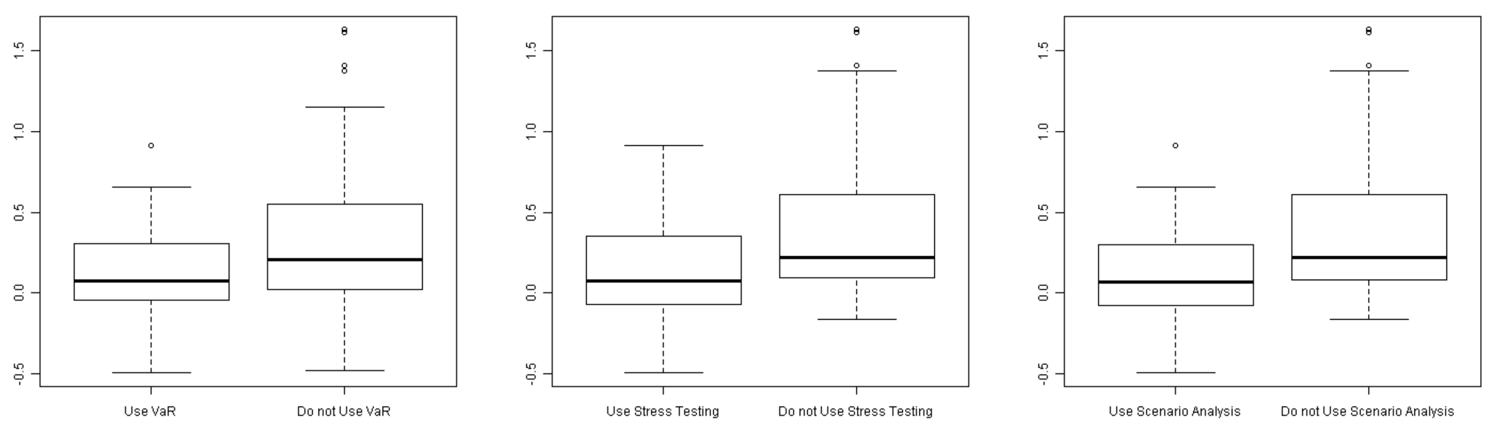

Figure 4: Accuracy of expectations of fund performance during a short-term equity bear market

This Figure plots mean and median fund cumulative performance for September through November 2008 (y-axis) against the manager's expected performance in a short-term equity bear market (x-axis) for the 90 funds with sufficient returns and expectations data. The scale for expected performance in a short-term equity bear market is as follows: -2 = "Down"; -1 = "Down (a little)"; 0 = "No effect"; 1 = "Up (a little)"; 2 = "Up."

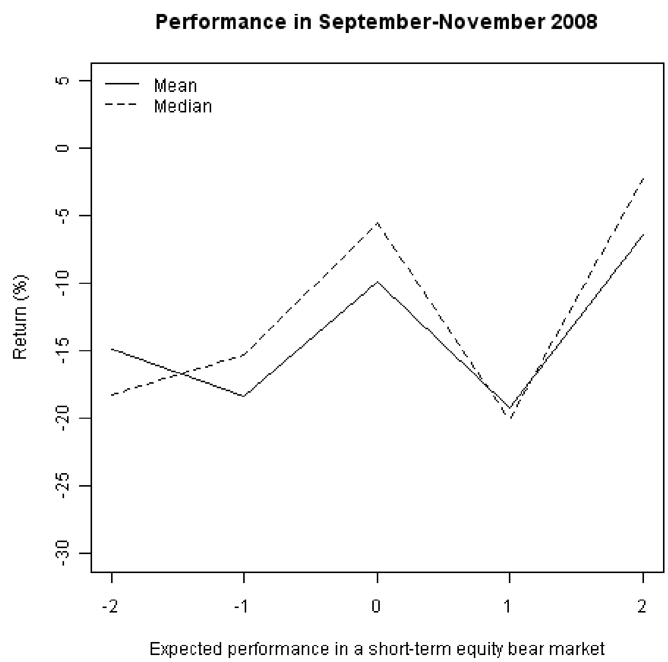

Figure 5: Value at risk and accuracy of expectations of fund performance during a short-term equity bear market

This Figure compares the accuracy of expectations for funds that do and do not use value at risk. The plots show mean and median fund cumulative performance for September through November 2008 (y-axis) plotted against the manager's expected performance in a short-term equity bear market (x-axis) for the 79 funds with sufficient returns, expectations, and risk management data. The scale for expected performance in a short-term equity bear market is as follows: -2 = "Down"; -1 = "Down (a little)"; 0 = "No effect"; 1 = "Up (a little)"; 2 = "Up."

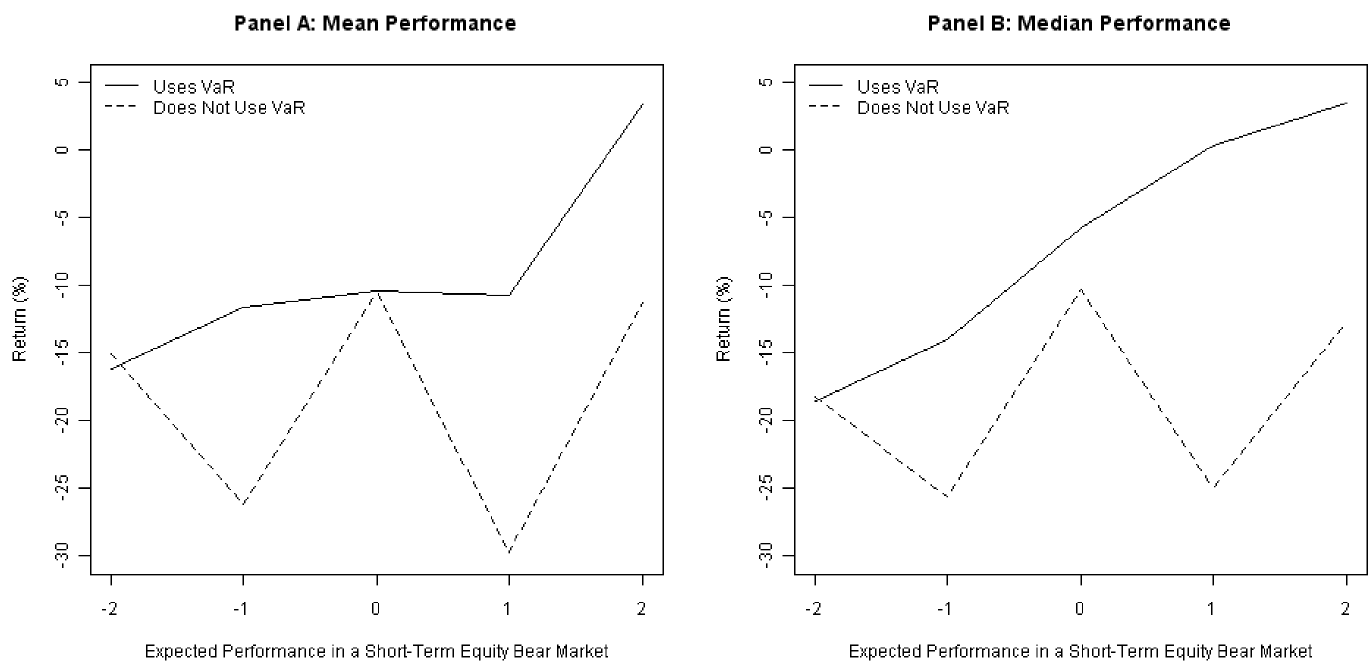

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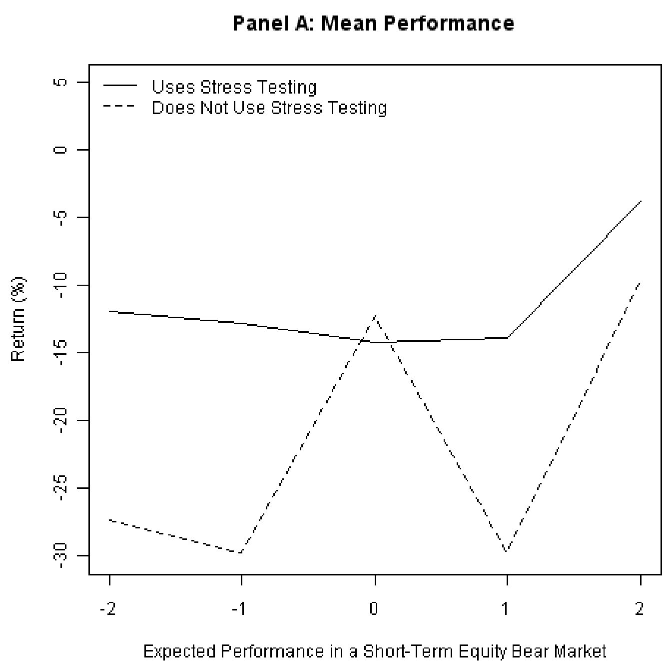
Figure 6: Stress testing and accuracy of expectations of fund performance during a short-term equity bear market

This Figure compares the accuracy of expectations for funds that do and do not use stress testing. The plots show mean and median fund cumulative performance for September through November 2008 (y-axis) plotted against the manager's expected performance in a short-term equity bear market (x-axis) for the 79 funds with sufficient returns, expectations, and risk management data. The scale for expected performance in a short-term equity bear market is as follows: -2 = "Down"; -1 = "Down (a little)"; 0 = "No effect"; 1 = "Up (a little)"; 2 = "Up."



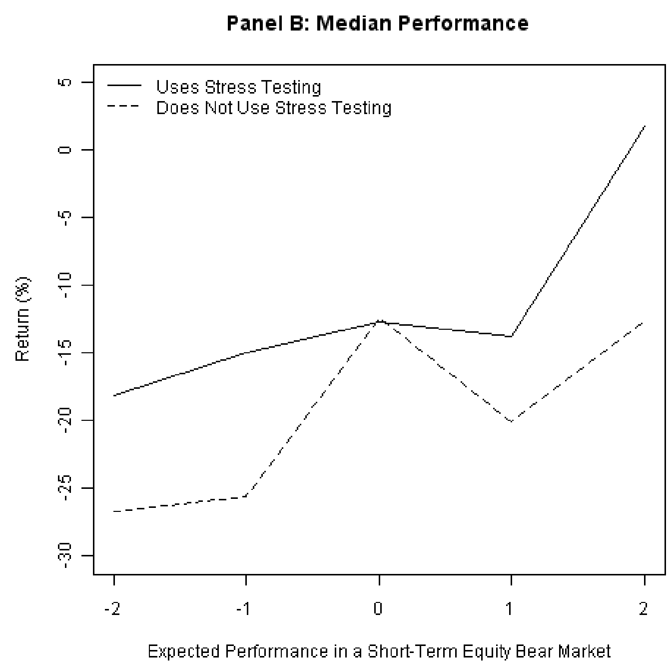


Figure 7: Scenario analysis and accuracy of expectations of fund performance during a short-term equity bear market

This Figure compares the accuracy of expectations for funds that do and do not use scenario analysis. The plots show mean and median fund cumulative performance for September through November 2008 (y-axis) plotted against the manager's expected performance in a short-term equity bear market (x-axis) for the 71 funds with sufficient returns, expectations, and risk management data. The scale for expected performance in a short-term equity bear market is as follows: -2 = "Down"; -1 = "Down (a little)"; 0 = "No effect"; 1 = "Up (a little)"; 2 = "Up."

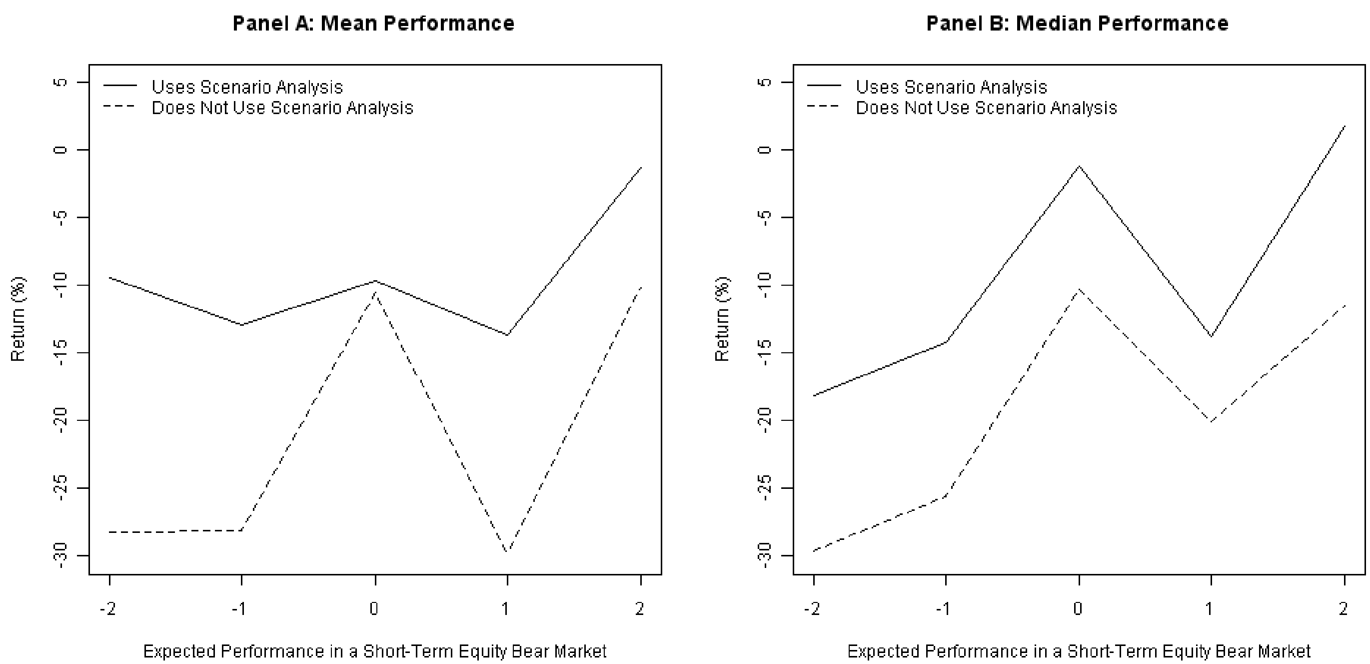


Table 1: Fund characteristics

This table presents descriptive statistics for the hedge funds in our sample. Assets under management and fund age are measured as of the date of due diligence. Assets under management is in thousands of US dollars. Investor assets represent investments by outsiders and Proprietary assets represent investments by the fund's manager and its employees. Leverage is an indicator for whether the fund uses explicit leverage. Long bias and Short bias are indicator variables for whether the fund's portfolio is tilted in either the long or short direction. Year, Quarters, Months, Weeks, and Days are indicator variables for the typical holding period of an investment position. 1000+ Positions, 200–999 Positions, 100–199 Positions, 40–99 Positions, and 1–39 Positions are indicator variables for the typical number of investment positions held by the fund.

	Mean	N	Std. Dev.	Q1	Median	Q3
Assets under management	304,783	423	652,378	40,000	107,000	269,000
Ln(Assets under management)	18.43	423	1.741	17.50	18.49	19.41
Ln(Investor assets)	14.46	423	7.59	16.01	17.80	19.01
Ln(Proprietary assets)	15.71	423	3.16	14.51	15.83	17.37
Age fund (days)	1,020	425	977	373	700	1,339
Ln(Age fund)	6.39	425	1.30	5.92	6.55	7.20
Leverage	0.54	425				
Long bias	0.36	421				
Short bias	0.20	421				
Fund offshore	0.84	424				
Years	0.32	424				
Quarters	0.31	424				
Months	0.15	424				
Weeks	0.09	424				
Days	0.13	424				
1000+ Positions	0.03	421				
200–999 Positions	0.08	421				
100–199 Positions	0.12	421				
40–99 Positions	0.35	421				
1–39 Positions	0.41	421				

Table 2: Portfolio risk management practices

This table presents descriptive statistics for the portfolio risk management practices used by the funds in our sample.

	Full sample		With returns & controls	
	%	N	%	N
Portfolio risk models				
Value at risk	43.7	387	41.8	110
Stress testing	52.1	380	52.7	112
Scenario analysis	46.4	364	45.2	104
At least one type	58.3	393	56.3	112
No models and testing	47.0	349	48.0	102
One type	7.7	349	6.9	102
Two types	8.9	349	9.8	102
All three types	36.4	349	35.3	102
Head of risk management				
Dedicated to risk management	34.0	262	33.8	77
No trading authority	25.8	361	21.1	95
Hedging authority only	4.2	361	2.1	95
Full trading authority	70.1	361	76.8	95
Position limits				
Hard limits	16.6	427	19.3	114
Guidelines	26.9	427	28.1	114
No limits	56.4	427	52.6	114

Table 3: Correlation matrix

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Value at risk	1.00													
2	Stress testing	0.71	1.00												
3	Scenario analysis	0.75	0.88	1.00											
4	At least one	0.78	0.93	0.85	1.00										
5	Risk officer dedicated	0.27	0.31	0.28	0.32	1.00									
6	Risk officer trading	0.25	0.21	0.23	0.27	0.75	1.00								
7	Position limits	0.08	0.03	−0.03	0.06	0.14	0.01	1.00							
8	Ln(Investor assets)	−0.02	−0.01	0.01	−0.01	0.01	−0.01	0.11	1.00						
9	Ln(Proprietary assets)	0.11	0.08	0.12	0.10	0.23	0.17	−0.01	0.39	1.00					
11	Ln(Fund age)	0.06	0.02	0.02	0.03	0.13	-0.01	0.13	0.12	0.28	1.00				
12	Leverage	0.25	0.24	0.23	0.06	0.22	0.16	0.01	−0.08	0.10	−0.01	1.00			
13	Long bias	0.14	0.19	0.23	0.21	0.08	0.09	0.06	−0.02	0.14	0.05	0.18	1.00		
14	Short bias	−0.01	0.02	−0.01	0.02	−0.10	−0.07	−0.01	−0.02	−0.04	−0.01	0.01	−0.22	1.00	
15	Fund offshore	0.16	0.14	0.11	0.13	0.08	0.07	0.14	−0.08	0.12	−0.08	0.08	0.06	−0.10	1.00

Table 4: Models of portfolio risk

This table presents results from tests of the determinants of portfolio risk models. The columns present marginal effects from probit regressions in which the dependent variable is coded as 1 if the fund uses the model type, and 0 otherwise. Standard errors are in parentheses.

	Value at risk	Stress testing	Scenario analysis	At least one
Ln(Investor assets)	0.001	0.003	−0.000	0.002
	(0.004)	(0.004)	(0.004)	(0.004)
Ln(Proprietary assets)	0.010	0.008	0.008	0.012
	(0.010)	(0.010)	(0.010)	(0.010)
Ln(Fund age)	0.008	−0.017	−0.011	−0.007
	(0.023)	(0.023)	(0.023)	(0.022)
Leverage	0.184***	0.142**	0.152***	0.170***
	(0.057)	(0.059)	(0.057)	(0.055)
Long bias	0.137**	0.231***	0.194***	0.210***
	(0.062)	(0.061)	(0.059)	(0.056)
Short bias	−0.012	0.027	0.052	0.050
	(0.073)	(0.075)	(0.071)	(0.068)
Fund offshore	0.233***	0.129	0.158**	0.162**
	(0.068)	(0.079)	(0.078)	(0.077)
Years	−0.221**	−0.151	−0.149	−0.214**
	(0.091)	(0.097)	(0.098)	(0.098)
Quarters	−0.186**	−0.086	−0.041	−0.120
	(0.090)	(0.096)	(0.097)	(0.098)
Months	0.017	0.112	0.082	0.018
	(0.110)	(0.111)	(0.107)	(0.108)
Weeks	0.070	0.062	0.113	0.074
	(0.126)	(0.133)	(0.128)	(0.120)
1000+ Positions	0.147	0.256	0.102	0.134
	(0.202)	(0.187)	(0.190)	(0.183)
200–999 Positions	0.172	0.140	0.297***	0.224***
	(0.109)	(0.111)	(0.087)	(0.086)
100–199 Positions	0.237***	0.189**	0.205**	0.172**
	(0.089)	(0.093)	(0.083)	(0.077)
40–99 Positions	0.165**	0.108	0.096	0.113*
	(0.064)	(0.065)	(0.063)	(0.060)
Year fixed effects	Included	Included	Included	Included
Observations	369	350	364	376
p Value	0.000	0.000	0.000	0.000
Log likelihood	-216.513	-212.639	-221.037	-220.190

* p<.1, ** p<.05, *** p<.01, two-sided test

Table 5: Head of risk management characteristics and responsibilities

This table presents results from tests of the determinants of characteristics and responsibilities of the head of risk management. The first column presents marginal effects from a probit regression in which the dependent variable is coded as 1 if the head of risk management is dedicated to risk management, and 0 otherwise. The second column presents coefficients from an ordered probit regression in which the dependent variable is coded as 2 if the head of risk management has no trading authority, 1 if he has hedging authority, and 0 if he has full trading authority. Standard errors are in parentheses.

	Dedicated	Trading
Ln(Investor assets)	0.007	0.013
	(0.006)	(0.011)
Ln(Proprietary assets)	0.056***	0.113***
	(0.020)	(0.038)
Ln(Fund age)	0.005	−0.137**
	(0.031)	(0.069)
Leverage	0.085	0.283*
	(0.068)	(0.164)
Long bias	−0.022	0.008
	(0.071)	(0.164)
Short bias	−0.085	−0.177
	(0.077)	(0.201)
Fund offshore	0.035	0.124
	(0.092)	(0.228)
Years	0.068	0.209
	(0.124)	(0.266)
Quarters	0.295**	0.353
	(0.124)	(0.257)
Months	0.347**	0.535*
	(0.145)	(0.294)
Weeks	0.385**	0.074
	(0.152)	(0.351)
1000+ Positions	0.514***	0.658*
	(0.156)	(0.390)
200–999 Positions	0.239*	0.541*
	(0.142)	(0.280)
100–199 Positions	0.031	0.104
	(0.106)	(0.245)
40–99 Positions	0.060	0.338*
	(0.078)	(0.179)
Year fixed effects	Included	Included
Observations	256	344
p Value	0.000	0.001
Log likelihood	−131.978	−231.738

* p<.1, ** p<.05, *** p<.01, two-sided test

Table 6: Limits on investment positions

This table presents results from tests of the determinants of position limits. It presents coefficients from an ordered probit regression in which the dependent variable is coded as 0 if the fund has no position limits, 1 if it has position guidelines, and 2 if it has hard limits. Standard errors are in parentheses.

	Limits
Ln(Investor assets)	0.022**
	(0.009)
Ln(Proprietary assets)	−0.002
	(0.023)
Ln(Fund age)	0.135**
	(0.055)
Leverage	0.028
	(0.128)
Long bias	0.186
	(0.135)
Short bias	−0.013
	(0.158)
Fund offshore	0.566***
	(0.180)
Years	−0.457**
	(0.214)
Quarters	−0.319
	(0.210)
Months	−0.781***
	(0.247)
Weeks	-0.331
	(0.274)
1000+ Positions	−1.327***
	(0.467)
200–999 Positions	−0.254
	(0.246)
100–199 Positions	−0.007
	(0.201)
40–99 Positions	0.178
	(0.140)
Year fixed effects	Included
Observations	407
p Value	0.000
Log likelihood	−372.333

* p<.1, ** p<.05, *** p<.01, two-sided test

Table 7: Univariate tests of association between portfolio risk models and performance in 2008

This table compares monthly mean performance in 2008 for funds that do and not use portfolio risk models. Differences are tested using two-sided t tests.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	**Oct**	Nov	Dec
S&P 500	−6.12	−3.48	−0.01	4.75	1.01	−8.60	−0.99	1.22	−9.08	**−16.94**	−7.48	0.78
HFR Composite	−2.69	1.50	−2.24	1.63	1.87	−1.33	−2.29	−1.44	−6.13	**−6.84**	−2.67	0.15
Value at risk												
Use	−0.273	2.355	−1.912	1.079	1.390	0.632	−1.609	−0.718	−3.591	**−2.256**	−1.906	−0.030
Do not use	−1.334	1.519	−1.647	0.804	1.614	−0.661	−2.539	−1.423	−5.190	**−8.334**	−3.723	−1.829
p Value	0.225	0.332	0.392	0.665	0.659	0.082	0.199	0.358	0.246	**0.003**	0.094	0.037
Observations	110	110	110	110	110	110	110	110	110	**110**	110	110
Stress testing												
Use	−0.424	2.110	−1.498	0.559	1.347	0.876	−1.450	−0.785	−3.092	**−3.734**	−2.246	−0.650
Do not use	−1.697	1.540	−2.280	1.184	1.988	−1.032	−3.192	−1.591	−6.846	**−9.227**	−3.969	−1.905
p Value	0.157	0.522	0.263	0.325	0.248	0.016	0.028	0.350	0.008	**0.010**	0.110	0.218
Observations	112	112	112	112	112	112	112	112	112	**112**	112	112
Scenario analysis												
Use	−0.330	2.166	−1.611	0.534	1.403	0.838	−1.630	−0.800	−2.927	**−2.801**	−2.233	−0.304
Do not use	−1.782	1.558	−2.012	1.370	1.812	−0.920	−2.749	−1.453	−6.192	**−9.241**	−4.136	−1.971
p Value	0.112	0.470	0.563	0.205	0.427	0.024	0.141	0.432	0.026	**0.002**	0.089	0.066
Observations	104	104	104	104	104	104	104	104	104	**104**	104	104
At least one model												
Use	−0.338	2.063	−1.524	0.658	1.353	0.819	0.353	−0.748	−3.002	**−3.525**	−2.092	−0.669
Do not use	−1.827	1.380	−2.134	1.296	1.843	−1.147	0.707	−1.574	−6.837	**−9.318**	−4.279	−2.087
p Value	0.105	0.446	0.381	0.299	0.370	0.018	0.039	0.360	0.006	**0.006**	0.048	0.167
Observations	112	112	112	112	112	112	112	112	112	**112**	112	112

Table 8: Multivariate tests of association between portfolio risk models and performance in 2008

This table presents ordinary least squares regressions that test the association between portfolio risk models and monthly performance in 2008. The dependent variable in each regression is the fund's return for the month. The control variables include the independent variables presented in Tables 4, 5, and 6 along with indicator variables for the fund's investment style, which are presented in the Appendix. Standard errors are in parentheses.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	**Oct**	Nov	Dec
S&P 500	−6.12	−3.48	−0.01	4.75	1.01	−8.60	−0.99	1.22	−9.08	**−16.94**	−7.48	0.78
HFR Composite	−2.69	1.50	−2.24	1.63	1.87	−1.33	−2.29	−1.44	−6.13	**−6.84**	−2.67	0.15
Value at risk	2.210**	0.394	0.275	−0.159	−0.608	2.036**	1.866**	1.968**	2.671*	**6.417*****	1.659	1.433
	(0.919)	(0.957)	(0.760)	(0.741)	(0.559)	(0.840)	(0.825)	(0.928)	(1.461)	**(2.108)**	(1.194)	(1.012)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
Observations	110	110	110	110	110	110	110	110	110	**110**	110	110
p Value	0.004	0.157	0.201	0.776	0.036	0.030	0.061	0.181	0.008	**0.001**	0.107	0.368
Adj. R^2	0.211	0.070	0.057	−0.055	0.134	0.141	0.113	0.063	0.187	**0.241**	0.089	0.020
Stress testing	1.792**	0.328	1.206	−0.848	−0.980*	2.388***	2.406***	1.401	4.403***	**6.041*****	1.908*	1.433
	(0.867)	(0.943)	(0.741)	(0.715)	(0.558)	(0.778)	(0.792)	(0.885)	(1.403)	**(2.126)**	(1.107)	(1.012)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
Observations	112	112	112	112	112	112	112	112	112	**112**	112	112
p Value	0.001	0.174	0.174	0.719	0.036	0.010	0.023	0.178	0.002	**0.005**	0.050	0.368
Adj. R^2	0.237	0.064	0.064	-0.043	0.132	0.176	0.148	0.062	0.223	**0.200**	0.119	0.020
Scenario analysis	2.842***	0.640	1.113	−1.454*	−0.642	2.869***	1.750**	1.235	5.271***	**7.686*****	2.432**	1.600
	(0.891)	(0.988)	(0.753)	(0.735)	(0.556)	(0.854)	(0.848)	(0.964)	(1.386)	**(2.090)**	(1.218)	(1.042)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
Observations	104	104	104	104	104	104	104	104	104	**104**	104	104
p Value	0.001	0.611	0.098	0.485	0.024	0.023	0.077	0.191	0.001	**0.001**	0.088	0.356
Adj. R^2	0.278	−0.025	0.099	-0.002	0.159	0.160	0.111	0.064	0.307	**0.285**	0.104	0.023
At least one model	2.237**	0.428	1.114	−0.955	−0.820	2.532***	2.481***	1.629*	4.475***	**5.999*****	2.247*	0.370
	(0.990)	(0.954)	(0.752)	(0.710)	(0.544)	(0.797)	(0.785)	(0.910)	(1.417)	**(2.131)**	(1.143)	(1.170)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
Observations	112	112	112	112	112	112	112	112	112	**112**	112	112
p Value	0.002	0.148	0.261	0.650	0.030	0.008	0.018	0.227	0.002	**0.005**	0.060	0.650
Adj. R^2	0.230	0.072	0.041	-0.030	0.138	0.182	0.156	0.049	0.220	**0.197**	0.115	-0.030

* p<.1, ** p<.05, *** p<.01, two-sided test

Table 9: Multivariate tests of association between portfolio risk models and performance in 2007 & 2009

This table presents ordinary least squares estimations of the association between fund performance in 2007 and in the first six months of 2009 and the portfolio risk models used by the fund. The dependent variable is the average monthly return over the period. The control variables include the independent variables presented in Tables 4, 5, and 6 along with indicator variables for the fund's investment style. Standard errors are in parentheses.

	Jan.–Dec. 2007	Jan.–Jun. 2009
Value at risk	−0.422	0.097
	(0.319)	(0.831)
Control Variables	Included	Included
Observations	110	100
p Value	0.663	0.744
Adj. R^2	−0.033	−0.054
Stress testing	−0.002	−0.935
	(0.304)	(0.887)
Control Variables	Included	Included
Observations	112	101
p Value	0.667	0.897
Adj. R^2	−0.033	−0.094
Scenario analysis	−0.279	−0.410
	(0.334)	(0.856)
Control Variables	Included	Included
Observations	104	93
p Value	0.707	0.573
Adj. R^2	−0.044	−0.020
At least one model	−0.104	−0.686
	(0.313)	(0.847)
Control Variables	Included	Included
Observations	112	101
p Value	0.649	0.685
Adj. R^2	−0.030	−0.041

* $p<.1$, ** $p<.05$, *** $p<.01$, two-sided test

Table 10: Univariate tests of association between portfolio risk models and performance in 2008 for long-short equity hedge funds

This table compares monthly mean performance in 2008 for long-short equity hedge funds that do and not use portfolio risk models. Differences are tested using two-sided t tests.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	**Oct**	Nov	Dec
S&P 500	−6.12	−3.48	−0.01	4.75	1.01	−8.60	−0.99	1.22	−9.08	**−16.94**	−7.48	0.78
HFR Equity Hedge (Total)	−4.47	1.31	−2.84	2.44	2.38	−2.44	−2.84	−2.17	−8.14	**−9.46**	−3.77	0.22
Value at risk												
Use	−2.091	3.578	−1.494	2.015	3.686	0.707	−0.499	−0.878	−2.736	**−2.114**	−0.373	0.919
Do not use	−6.917	1.010	−7.016	2.097	1.683	−4.911	−7.247	−6.200	−11.648	**−18.586**	−4.006	−0.565
p Value	0.038	0.334	0.009	0.966	0.309	0.036	0.005	0.112	0.021	**0.009**	0.176	0.568
Observations	27	27	27	27	27	27	27	27	27	**27**	27	27
Stress testing												
Use	−3.653	1.639	−1.830	2.047	2.177	1.045	−0.785	−1.442	−3.302	**−4.682**	−1.400	0.543
Do not use	−5.165	3.052	−6.669	1.099	3.691	−4.835	−7.444	−5.503	−12.222	**−16.574**	−3.159	0.267
p Value	0.472	0.560	0.018	0.627	0.433	0.015	0.004	0.186	0.017	**0.043**	0.471	0.908
Observations	29	29	29	29	29	29	29	29	29	**29**	29	29
Scenario analysis												
Use	−3.372	1.264	−1.914	2.259	1.845	0.884	−0.914	−1.165	−3.900	**−2.626**	−0.900	0.844
Do not use	−6.219	3.281	−6.444	1.921	3.359	−4.344	−6.706	−5.642	−10.544	**−16.887**	−3.659	−0.554
p Value	0.191	0.408	0.022	0.855	0.413	0.041	0.009	0.151	0.072	**0.016**	0.272	0.560
Observations	26	26	26	26	26	26	26	26	26	**26**	26	26
At least one model												
Use	−3.024	1.524	−1.740	1.911	2.019	0.989	−0.800	−1.286	−2.883	**−4.283**	−1.231	0.458
Do not use	−6.251	2.699	−6.944	2.085	3.364	−6.021	−7.541	−5.970	−12.693	**−16.635**	−3.687	−0.131
p Value	0.168	0.670	0.023	0.932	0.523	0.011	0.009	0.195	0.017	**0.049**	0.393	0.834
Observations	29	29	29	29	29	29	29	29	29	**29**	29	29

Table 11: Descriptive statistics for manager education

This table presents descriptive statistics for manager education. Team (%) presents the mean for the percentage of the management team or the risk management team with the relevant degree. At least one (%) presents the percentage of funds in which at least one member of either the management team or the risk management team has the relevant degree.

	Risk management team		Management team	
	Team (%)	At least one (%)	Team (%)	At least one (%)
Undergraduate degree in either business or economics	57	60	54	83
Undergraduate degree in science or engineering	19	22	14	36
Masters degree in either business or economics	43	45	41	71
Masters degree in science or engineering	7	8	4	12
Ph.D.	12	13	11	27
Number of funds	233		399	

Table 12: Models of portfolio risk controlling for education

This table presents results from tests of the determinants of portfolio risk models. The columns present marginal effects from probit regressions in which the dependent variable is coded as 1 if the fund uses the model type, and 0 otherwise. The control variables are the same independent variables used in Table 4. Standard errors are in parentheses.

	Value at risk	Stress testing	Scenario analysis	At least one
Undergraduate degree in either business or economics	0.055	−0.011	−0.043	−0.026
	(0.096)	(0.097)	(0.094)	(0.092)
Undergraduate degree in science or engineering	0.134	0.176	0.120	0.076
	(0.148)	(0.153)	(0.150)	(0.145)
Masters degree in either business or economics	0.072	0.023	0.019	0.058
	(0.090)	(0.093)	(0.090)	(0.086)
Masters degree in science or engineering	0.453*	0.649**	0.447	0.387
	(0.274)	(0.301)	(0.299)	(0.279)
Ph.D.	0.103	0.235	0.215	0.156
	(0.149)	(0.150)	(0.146)	(0.143)
Control variables	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes
Observations	346	329	343	353
p Value	0.000	0.000	0.000	0.000
Log likelihood	−195.443	−192.437	−204.982	−204.051

Table 13: Multivariate tests of association between portfolio risk models and performance in 2008 controlling for education

This table presents ordinary least squares regressions that test the association between portfolio risk models and monthly performance in 2008 controlling for manager education. The dependent variable in each regression is the fund's return for the month. The control variables include the independent variables presented in Tables 4, 5, and 6 along with indicator variables for the fund's investment style, which are based on the Lipper TASS and HFR style designations. Standard errors are in parentheses.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	**Oct**	Nov	Dec
S&P 500	−6.12	−3.48	−0.01	4.75	1.01	−8.60	−0.99	1.22	−9.08	**−16.94**	−7.48	0.78
HFR Composite	−2.69	1.50	−2.24	1.63	1.87	−1.33	−2.29	−1.44	−6.13	**−6.84**	−2.67	0.15
At least one model	3.184***	0.137	1.503*	−1.372	−1.226*	2.753***	2.795***	1.610	5.607***	**6.052****	2.709**	0.070
	(1.025)	(1.080)	(0.848)	(0.848)	(0.622)	(0.843)	(0.909)	(1.025)	(1.592)	**(2.447)**	(1.225)	(1.386)
Under. bus. or econ.	2.145	−2.809	4.879***	−0.403	0.116	1.843	1.179	1.723	2.613	**8.598***	1.708	0.992
	(1.960)	(2.067)	(1.623)	(1.622)	(1.190)	(1.612)	(1.739)	(1.962)	(3.046)	**(4.681)**	(2.343)	(2.653)
Under. science	2.595	−6.116*	5.746**	−0.647	−1.861	−0.435	5.013*	4.364	5.145	**6.817**	2.199	0.452
	(3.024)	(3.189)	(2.503)	(2.502)	(1.836)	(2.488)	(2.684)	(3.027)	(4.700)	**(7.222)**	(3.615)	(4.092)
Masters bus. or econ.	−3.840**	−4.073**	0.041	1.517	−1.734	−1.453	2.022	0.868	-1.022	**−2.579**	−4.263**	−2.376
	(1.775)	(1.871)	(1.469)	(1.468)	(1.077)	(1.460)	(1.575)	(1.776)	(2.758)	**(4.237)**	(2.121)	(2.401)
Masters science	2.001	−2.239	−2.856	0.911	−1.718	−7.635	−0.639	2.096	−12.254	**-3.491**	−22.499***	3.120
	(6.506)	(6.860)	(5.385)	(5.381)	(3.948)	(5.351)	(5.772)	(6.511)	(10.110)	**(15.534)**	(7.775)	(8.803)
Ph.D.	−0.249	−1.404	1.814	1.364	1.577	3.133	−0.348	0.987	7.475*	**10.489**	0.910	6.156*
	(2.696)	(2.843)	(2.232)	(2.230)	(1.636)	(2.218)	(2.392)	(2.698)	(4.190)	**(6.438)**	(3.222)	(3.648)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**Yes**	Yes	Yes
Observations	96	96	96	96	96	96	96	96	96	**96**	96	96
p Value	0.018	0.827	0.141	0.476	0.143	0.101	0.140	0.399	0.005	**0.032**	0.040	0.797
Adj. R^2	0.216	−0.093	0.107	−0.068	0.106	0.128	0.107	0.022	0.271	**0.190**	0.179	−0.083

* p<.1, ** p<.05, *** p<.01, two-sided test

Table 14: Multivariate tests of association between portfolio risk models and betas

This table presents ordinary least squares regressions that test the association between portfolio risk models and the fund's beta. We estimate the betas over the 30 month period starting in January 2007 and ending in June 2009. We use the return on the S&P500 Index as the market return. The control variables include the independent variables presented in Tables 4, 5, and 6 along with indicator variables for the fund's investment style, which are based on the Lipper TASS and HFR style designations. Standard errors are in parentheses.

	Betas							
Value at risk	−0.205**	−0.269***						
	(0.079)	(0.085)						
Stress testing			−0.299***	−0.352***				
			(0.082)	(0.082)				
Scenario analysis					−0.281***	−0.389***		
					(0.078)	(0.082)		
At least one model							−0.284***	−0.350***
							(0.078)	(0.082)
Control Variables	No	Yes	No	Yes	No	Yes	No	Yes
Observations	102	100	93	93	101	101	102	101
p Value	0.011	0.017	0.000	0.001	0.001	0.004	0.000	0.005
Adj. R^2	0.053	0.188	0.119	0.316	0.104	0.236	0.109	0.231

* p<.1, ** p<.05, *** p<.01, two-sided test

Table 15: Expected performance during a short equity bear market

This table presents the distribution of the managers' expected performance during a short-term equity bear market. It further classifies expected performance by the funds' risk management practices and presents p values from Chi-square tests of whether there is a relation between expectations and risk management practices.

		−2	−1	0	+1	+2		
		Down a lot	Down a little	No effect	Up a little	Up a lot	Total	p Value
All funds		46	59	66	26	39	236	
Value at risk	Yes	19	27	26	12	21	105	
	No	23	21	31	12	15	102	0.640
Stress testing	Yes	26	23	29	13	17	108	
	No	15	24	25	11	19	94	0.629
Scenario analysis	Yes	19	22	27	11	12	91	
	No	18	21	26	11	23	99	0.526
At least one model	Yes	29	26	34	14	21	124	
	No	15	20	24	10	17	86	0.733
Risk officer	Yes	17	14	15	9	14	69	
dedicated	No	25	40	46	15	23	149	0.312
Risk officer	Yes	29	44	50	18	26	167	
trading authority	No	13	9	11	7	11	51	0.312
Position limits	Hard limits	10	10	8	4	5	37	
	Guidelines	12	16	16	11	10	65	
	No limits	24	33	42	11	24	134	0.633