The Behavior of Hedge Funds during Liquidity Crises

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Abstract

To shed light on the empirical relevance of the limits to arbitrage, we study hedge funds' trading patterns in the stock market during liquidity crises. Consistent with arbitrageurs' limited ability to provide liquidity, we find that at the time of liquidity crises hedge funds reduce their equity holdings by 9% to 11% per quarter (around 0.3% of total market capitalization). Dramatic selloffs took place during the 2008 crisis: hedge funds sold about 30% of their stock holdings and nearly every fourth hedge fund sold more than 40% of its equity portfolio. We identify two main drivers of this behavior. First, in line with the limits-to-arbitrage theory, we document that lender and investor funding withdrawals explain over half of the equity selloffs. Second, it appears that hedge funds mobilize capital to other (potentially less liquid) markets in pursuit of more profitable investment opportunities. The latter finding suggests that liquidity provision by arbitrageurs is not entirely hampered.

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1. Introduction

It is widely believed that hedge funds provide liquidity to markets (see, e.g., Agarwal, Fung, Loon, and Naik 2007). According to this view, hedge funds act as arbitrageurs by reducing the liquidity premium on assets that are less desirable and eliminating market mispricing. For example, Brophy, Paige, and Sialm (2009) present evidence that hedge funds provide liquidity in niche assets when other classes of investors are reluctant to invest due to the high degree of information asymmetry. Also consistent with this belief, Khandani and Lo (2009) document that the returns of hedge funds are correlated with the returns of illiquid assets, and Aragon (2007) and Sadka (2009) find that hedge funds earn premia related to liquidity level and risk, respectively.

However, theories by Shleifer and Vishny (1997), Gromb and Vayanos (2002), Vayanos (2004), and Brunnermeier and Pedersen (2009) suggest that there can be limits to arbitrageurs' ability to provide liquidity, especially during periods of market tension when capital becomes more expensive. To illustrate, Brunnermeier and Pedersen (2009) suggest that negative shocks to arbitrageurs' trading capital ("funding liquidity") may limit their ability to reduce deviations of prices from fundamentals ("market liquidity"). In their model, a dry-up in funding liquidity and a deterioration in market liquidity can reinforce each other ("liquidity spirals"). In the process, arbitrageurs rebalance their portfolios towards more liquid assets, which require less capital for trading ("flight to quality"). An important prediction of this theory is the existence of multiple equilibria in which arbitrageurs can either provide liquidity to markets or contribute to liquidity dry-ups. Which equilibrium better describes financial markets is an empirical question.

The limited empirical evidence on hedge fund trading during a crisis seems to confirm that hedge funds are affected by funding liquidity. Cao, Chen, Liang, and Lo (2009) find that hedge funds manage their portfolios to reduce market exposure at times of low liquidity. Hameed, Kang, and Viswanathan (2010) show that stock-level liquidity drops following stock price declines. They argue that this relation is driven by the financial constraints that arbitrageurs face following price shocks. Aragon and Strahan (2010) document that the liquidity of stocks held by Lehman-funded hedge funds deteriorated once their funding was cut off following Lehman's bankruptcy. Finally, Nagel (2009) shows that the returns from providing liquidity for Nasdaq stocks increased sharply in the recent financial crisis, suggesting that arbitrageurs withdrew from the market.

The goal of this paper is to provide this debate with further empirical evidence on the ability of arbitrageurs to supply liquidity at times of market stress. To this purpose, we focus on hedge funds' trading in the equity market during financial crises. Crises provide the best environment to test the limits-of-arbitrage theories because of the high reward for liquidity provision and the significant erosion of arbitrageurs' capital. At these times, if markets are described by the "good" equilibrium in which arbitrageurs provide liquidity, one would expect hedge funds to expand their portfolio. On the contrary, in the "bad" equilibrium in which arbitrageurs absorb liquidity, one should observe that hedge funds unwind their positions. We let the data tell us which situation applies in reality. In addition, the limits-to-arbitrage view postulates that the determinant of arbitrageurs' liquidations is capital withdrawals. We test whether this channel is an important determinant of hedge fund behavior. Finally, we bring to the data the cross-sectional prediction of flights to quality. In particular, we analyze hedge funds' trades of high-volatility stocks during financial crises.

An important caveat to our approach relates to the exclusive focus on the equity portfolio of hedge funds. Finding that hedge funds sell stocks does not necessarily imply that liquidity provision is limited if the proceeds are invested in more illiquid markets. Because of the nature of our data, we do not directly observe trades in assets other than U.S. stocks. Still, we are able to mitigate this concern by extending our analysis to total fund returns. In particular, we test whether the returns on the non-equity part of the portfolio are consistent with liquidity provision to other markets.

Our analysis relies on an original dataset. The main results are based on stock and option holdings by hedge funds from the 13F mandatory quarterly filings. These data are free from the self-reporting bias that affects commercial data sets (Agarwal, Fos, and Jiang 2010). We are able to identify hedge funds thanks to a proprietary list of hedge funds provided by Thomson-Reuters and by careful hand matching. Part of our analysis draws on TASS for hedge fund characteristics and monthly returns. Finally, since 13F filings cover only long stock and option positions, we also use stock-level short interest data in order to have an indirect view of arbitrageurs' positions on the short side of trades.

We document that hedge funds significantly reduce their equity holdings during periods of liquidity dry-ups. In the aggregate, hedge funds' participation in the equity market declines by

about 9% to 11% (around 0.3% of the total market capitalization) when market liquidity deteriorates by two standard deviations. During the crisis of 2008, hedge funds reduced their holdings more dramatically: in the last two quarters of the year, they cut their equity portfolio by about 30%, which corresponded to about 1% of the total equity market capitalization. Consistently throughout our analysis, we find that hedge funds respond to crises defined according to stock market liquidity factors (Pastor and Stambaugh 2003, Acharya and Pedersen 2005), but not according to measures of aggregate uncertainty (VIX index) or to pure market crashes.

Brunnermeier and Pedersen (2009) postulate that increased margin requirements affect arbitrageurs' ability to hold short as well as long positions. In order to close a short position, a hedge fund needs to buy shares on the market. Hence, if hedge funds are obliged to close short positions in the same stocks for which they unwind their long positions, the negative impact on liquidity of the selloffs may be lessened. Consistent with tighter margins, we find that short sellers unwind their positions significantly more strongly during liquidity crises. The magnitude of the effect is similar to the magnitude of stock sales by hedge funds, especially in 2008. However, we find that there is little overlap between the subset of stocks sold by hedge funds during liquidity crises and the short positions that are closed. Hence, closing short positions does not compensate for the liquidity that is consumed by the hedge funds' selloffs.

We also provide some disaggregated evidence. We find that the decline in equity participation among hedge funds is not uniformly spread across all hedge funds, but rather driven by a limited set of funds, which sell large portions of their portfolios. In quarters with low aggregate liquidity, 12% of hedge funds sell more than 40% of their equity portfolios, compared with 4.5% unconditionally. In each of the last two quarters of 2008, 23% of hedge funds sold more than 40% of their equity portfolio. In any case, the evidence that hedge funds increase their exposure to the equity market is limited to a few small funds. Hence, one cannot conclude that an important fraction of the population of hedge funds increases its stock market participation.

Given that hedge funds overall exit the equity market during a crisis, it is interesting to explore which other classes of investors absorb hedge funds' equity positions at times when aggregate liquidity deteriorates. We find that mutual funds do not change their equity holdings significantly during a crisis. Rather, they significantly drop equity when liquidity experiences a

mild deterioration. Other institutional investors (such as banks, insurance firms, and pension funds) seem in general to take the other side of hedge fund trades in a time of crisis. In 2008, however, it appears that retail investors were the ultimate liquidity providers.

Next, we turn to identifying the main channels that drive hedge fund behavior during liquidity crises. We identify two forces that cause hedge funds to decrease their equity holdings: capital outflows and an internal reallocation of funds across asset classes.

First, we document that a tightening of the capital available for arbitrage on the part of both investors and lenders causes hedge funds to reduce their equity positions. Shleifer and Vishny (1997) argue that investors may pull their funds if they are concerned that arbitrage trades may not converge, thus inducing arbitrageurs to avoid taking long-term bets. We find that investor redemptions explain between 20% and 40% of hedge fund stock sales during liquidity crises, depending on the measure of aggregate liquidity. Moreover, Brunnermeier and Pedersen (2009) argue that margin calls can limit arbitrageurs' ability to provide liquidity ("destabilizing margins"). In support of this explanation, we document that hedge funds with higher average leverage (which are likely to be subject to greater pressures by lenders) sell larger portions of their equity portfolio during liquidity crises. This effect, combined with investors' redemptions, explains on average 60% equity sales by hedge funds during crises. Also consistent with the predictions in Brunnermeier and Pedersen (2009), we find that hedge funds are more likely to close positions in high volatility stocks (both long and short) than in low volatility stocks. The flight-to-quality effect is also predicted by Vayanos (2004), who postulates that volatile assets make arbitrageurs' capital more subject to redemptions in bad times.

Second, we document that hedge funds that sell equities during liquidity crises reallocate part of their capital away from the equity market to other asset types, which are expected to outperform stocks. Specifically, holdings of equity put options during liquidity crises are a significant determinant of hedge fund selloffs. This finding relates stock sales to a negative outlook on the stock market by fund managers. Also, hedge funds that exit the stock market during liquidity dry-ups tend to be familiar with other markets, as they pursue multi-market strategies like managed futures, global macro, multi-strategy, and emerging markets. This finding is consistent with the evidence in Cao, Chen, Liang, and Lo (2009) on liquidity management by some the hedge funds following these styles. Finally, exiting hedge funds earn

high returns on their non-equity portfolio in the second quarter following liquidity crises, consistent with the idea that they mobilize capital towards mispriced assets in other markets. To illustrate, two quarters after a liquidity crisis, hedge funds that sell large portions of their portfolio during the crisis earn up to 11% more on their non-equity portfolio relative to funds that stay in the equity market.

The last set of results suggests that the limits-to-arbitrage view is not a full description of arbitrageurs' behavior in financial crises. Our evidence reveals that hedge funds are able to reallocate some of their capital to more attractive trades in other markets. Hence, the verdict on the role of hedge funds as liquidity providers cannot be entirely negative.

Our results relate to other empirical literature on the role of arbitrageurs in financial markets. The findings about the effects of capital constraints on hedge funds' trading patterns corroborate previous empirical results on the limits of arbitrage (Aragon and Strahan 2009, Hombert and Thesmar 2009, Hameed, Kang, and Viswanathan 2010). Also, the evidence on selloffs at times of crisis relates to the literature that argues that arbitrageurs act as a destabilizing force in financial markets. Consistent with this view, Khandani and Lo (2007) provide suggestive evidence that the quant crisis in August 2007 was possibly due to the unwinding of large hedge fund positions and to the increased correlation of hedge fund trades. Similarly, Boyson, Stahel, and Stulz (2008) show significant evidence of contagion in the hedge fund sector, which is reinforced at times of low liquidity. Finally, we see our result that hedge funds flee equity in bad times as symmetric to the finding that hedge funds ride bubbles in good times (Brunnermeier and Nagel 2004).

The paper proceeds as following. Section 2 describes the data sources that we use. In Section 3, we explore the aggregate behavior of hedge funds during liquidity crises and study the distribution of hedge fund trades. Section 4 takes a close look at the determinants of hedge fund behavior and investigates cross-sectional predictions of the limits-of-arbitrage theories. Section 5 concludes.

2. Data

2.1. Data Sources

We use several sources of data in our study. Our primary data source is the 13F mandatory institutional holdings reports that are filed with the SEC on a calendar quarter basis.[1] The Thomson-Reuters institutional holdings database (formerly known as the 13F CDA Spectrum 34 database) provides institutional holdings as reported on Form 13F filed with the SEC. Form 13F requires all institutions with investment discretion on over $100 million to report their long holdings (mainly publicly traded equity, convertible bonds, and options).[2] Therefore, all hedge funds with assets under management in such qualified securities of more than $100 million are required to report their holdings in 13F filings on a quarterly basis.[3] Also, hedge funds report their holdings in public equity, convertible bonds, and options at the consolidated management company level.

We then match the list of 13F institutions in Thomson-Reuters with a proprietary list of 13F hedge fund managing firms and other institutional filers, provided by Thomson-Reuters. The combined dataset allows us to identify the entities in the 13F reports that are firms that manage hedge funds.[4] Before applying the filters described below, the number of hedge funds in the Thomson-Reuters list varies from several dozen in the early 1980s to over 1,000 at the 2007 peak. We cross-check our list of hedge funds with the FactSet database and we find it congruent with the FactSet LionShares identification of hedge fund companies.

It is worth stressing that Thomson-Reuters's proprietary list of hedge funds provides us with an edge over previous studies that use 13F filings to infer hedge fund stock holdings.

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[1] According to Lemke and Lins (1987), Congress justified the adoption of Section 13F of the Securities Exchange Act in 1975 because, among other reasons, it facilitates consideration of the influence and impact of institutional managers on market liquidity: "Among the uses for this information that were suggested for the SEC were to analyze the effects of institutional holdings and trading in equity securities upon the securities markets, the potential consequences of these activities on a national market system, block trading and market liquidity…"

[2] With specific regard to equity, this provision concerns all long positions greater than 10,000 shares or $200,000 over which the manager exercises sole or shared investment discretion. The official list of Section 13F securities can be found on the following SEC webpage: http://www.sec.gov/divisions/investment/13Flists.htm

[3] More information about the requirements of Form 13F pursuant to Section 13F of the Securities Exchange Act of 1934 can be found at: http://www.sec.gov/divisions/investment/13Ffaq.htm.

[4] As a shortcut, from now on we will refer to the observational unit in our data set as a 'hedge fund'. It should be clear, however, that 13F provides asset holdings at the management firm level. Each firm reports consolidated holdings for all the funds that it has under management.

Relative to the self-reported industry lists that are commonly used to identify hedge funds, the Thomson list is certainly more comprehensive as it classifies all 13F filers. This comprehensiveness depends on Thomson's long-lasting and deep involvement with institutional filings. The SEC has long contracted the collection of various institutional data out to Thomson-Reuters, even when those reports were paper filings or microfiche in the public reference room. They also have directories of the different types of institutions, with extensive information about their businesses and staff. The list of hedge funds to which we have access is normally used by Thomson-Reuters for their consulting business and, to the best of our knowledge, has not been provided to other academic clients.[5]

While Thomson-Reuters collects all the institutional reports filed with the SEC, they only retain the common equity holdings in their 13F institutional holdings database. To be able to capture the stock options held by hedge funds with 13F institutional holdings reports, we downloaded and parsed all 13F electronic forms since 1999 available on the SEC website, a method similar to that of Aragon and Martin (2009). The SEC requires institutions to separately report all call and put options for a large set of 13F securities.[6,7] We looked only at the original 13F reports that are filed within forty-five days of the end of the calendar quarter, and mapped the list of our hedge funds to the CIKs they used in reporting SEC filings.[8,9]

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[5] References to Thomson-Reuters (or the companies that it acquired, such as CDA/Spectrum, which was formerly known as Disclosure Inc. and Bechtel) can be found at: 1. http://www.sec.gov/rules/final/33-8224.htm (search for Thomson); 2. SEC Annual Reports, 1982, http://www.sec.gov/about/annual_report/1982.pdf (page 37, or 59 of the pdf file); 3. http://www.sec.gov/rules/final/33-7432.txt (search for contractor); 4. http://www.sec.gov/about/annual_report/1989.pdf (search for contractor).

[6] The official list of Section 13F securities refer to options by their underlying securities: http://www.sec.gov/divisions/investment/13flists.htm, and requires CALL or PUT designations for options in the issuer description field. We used such "CALL" and "PUT" strings to identify option positions in 13F filings, where they appear under Item 2 or Item 6 or as a suffix to the company name in the body of the holdings table of the 13F report. Note that some filings used different identifiers for options, such as Goldman Sachs Group, which uses "CAL" for call options. We were able to capture and identify many such special cases.

[7] As an accuracy check, we compared the common equity portion of our parsed 13F dataset with the common equity holdings in the Thomson-Reuters 13F institutional ownership data, and we found a 99% correlation.

[8] We noticed that several hedge funds filed subsequent amendments with regard to their confidentially-treated holdings, which were excluded from the original 13F filings, but reported in the form of amendments only after the expiration or rejection of the confidential treatment requests. We also noticed that the Thomson-Reuters data usually excludes such individual holdings from their data; it is published as originally reported and apparently overlooks subsequent amendments. We rely on Thomson-Reuters 13F holdings data as it has better historical coverage from 1980 than the electronic 13F filings that have been posted on the SEC website since 1999. See Agarwal, Jiang, Tang, and Yang (2009) for more information about and statistics on the confidentially-treated holdings (Table 2, Panel B).

In addition to Thomson-Reuters' proprietary classification of hedge funds, we map hedge funds' 13F data to fund characteristics and monthly returns that are collected by Thomson-Reuters' Lipper-TASS database (drawn in August 2009). We use hedge fund company names in TASS and map it to the advisor company name that appears in 13F filings. The Lipper-TASS database provides hedge fund characteristics (such as investment style and average leverage) and monthly return information at the strategy or portfolio level. We aggregate the TASS data at the management company level, and match it to the 13F dataset using the consolidated management company name.[10]

Table 1, Panel D, provides the number of hedge funds in our sample by year, along with the fraction of hedge funds that are matched with TASS data. We notice that our TASS-matched sample increases significantly after 2000, but misses a lot of hedge fund companies that are classified by Thomson-Reuters as hedge funds and file 13F filings.[11] The main advantage of our dataset is that it includes most, if not all, hedge funds that are required to report their holdings in 13F filings. Thus, our dataset is broader and more comprehensive than those of prior studies. For example, Griffin and Xu (2009) have a total of 306 different hedge fund companies (Table 1, Panel A, in their paper) whereas, after applying the sample selection criteria that we describe below, we end up with 998 distinct hedge fund companies over the entire sample period. In addition to the reliance on the comprehensive list of hedge funds provided by Thomson, the larger number of funds also results from the fact that our sample period extends to a period that witnessed an explosion in the number of funds. An additional advantage of our data is that the 13F filings are not plagued by the selection and survivorship bias that occurs when relying on TASS and other self-reported databases for hedge fund identification (Agarwal, Fos, and Jiang 2010). Finally, the Thomson-Reuters hedge fund list identifies hedge funds at the disaggregated

[9] Firms can delay their 13F reporting to a limited number of stocks by up to one year, by applying for confidential filing. Agarwal, Jiang, Tang, and Yang (2010) find that about 3% of all filings are not complete as they include positions that are filed in the confidential section. They note that a large fraction of the confidential filers consist of hedge funds that use confidential filings to protect trades that are based on private information. In particular, hedge funds use confidential filings when building block ownership positions or acquiring stocks following merger announcements (as part of a merger arbitrage strategy). It appears, therefore, that our study should not be materially biased due to confidential filings as we are interested in dispositions following public events.

[10] We used strategy portfolio assets as weights in aggregating fund characteristics and total reported returns.

[11] Griffin and Xu (2009) use a TASS sample that ends in 2000 and rely on other hedge fund databases to classify hedge funds with 13F filings. We notice from our 2009 TASS sample that the hedge fund coverage in TASS increases significantly after 2000, but it is still likely to suffer from selection bias because it appears that many hedge funds with 13F filings are not in TASS.

advisor level, not at the 13F report consolidated level. For example, for Blackstone Group holdings in 13F data, Thomson-Reuters provided us with a classification of each of the advisors within Blackstone that reported its holdings in the same filing.[12]

Because many financial advisors manage hedge-fund-like operations, we need to apply a number of filters to the data. In order to limit our analysis to hedge funds, we drop institutions that have many advisors with non-hedge-fund business (e.g., Goldman Sachs Group, JP Morgan Chase & Co., American International Group Inc.), even though they have hedge funds that are managed in-house and included with their holdings in the parent management company's 13F report. Thomson-Reuters' hedge fund list also provides the classification of non-hedge fund entities that file under the same 13F entity. We used this list to screen out all companies with other reported non-hedge fund advisors that file their 13F holdings along with their hedge funds. Additionally, we manually verified that large investment banks and prime brokers that might have internal hedge fund business are excluded from our list. As a further filter, we double-checked the hedge fund classification by Thomson-Reuters against a complete list of ADV filings by investment advisors since 2006.[13] We matched those filings by advisor name to our 13F data. Then, following Brunnermeier and Nagel (2004), we kept only the institutions with more than half of their clients classified as "High Net Worth Individuals" or "Other Pooled Investment Vehicles (e.g. Hedge Funds)" in Item 5.D (Information About Your Advisory Business) of Form ADV. Therefore, we believe that our final list of hedge funds contains only institutions with the majority of their assets and reported holdings in the hedge fund business.

We compare the hedge fund population obtained from 13F to the matched population of hedge funds in TASS. Table 1, Panel D, presents the annual number of hedge funds in our sample that are required to report their holdings through 13F filings, and the number of matched hedge funds who self-reported their total returns, and individual fund characteristics to Lipper-TASS. The panel suggests that the matched sample contains only about 20% of the universe of

[12] There are three advisor entities within Blackstone Group L.P. that report their holdings in the same consolidated Blackstone Group report. Among the three advisors included, GSO Capital Partners and Blackstone Kailix Advisors are classified by Thomson-Reuters as Hedge Funds (which an ADV form confirms), while Blackstone Capital Partners V LP is classified as an Investment Advisor. See the "List of Other Included Managers" section in the September 30 2009 Blackstone 13F reports filed on November 16 2009:
http://www.sec.gov/Archives/edgar/data/1393818/000119312509235951/0001193125-09-235951.txt

[13] All current advisor ADV filings are available on the SEC's investment advisor public disclosure website: http://www.adviserinfo.sec.gov/IAPD/Content/Search/iapd_OrgSearch.aspx

hedge funds filing 13F forms. The panel also shows the explosion in the number of hedge funds over the last decade, and is consistent with the recent patterns of hedge fund liquidations at the end of 2008 and in the first three quarters of 2009. According to Hedge Fund Research Inc., the total assets managed by hedge funds decreased by around 19% by 2009, due to the market crisis and the record-setting hedge fund closures in 2008 and 2009.[14] This pattern is strongly reflected in Figure 1, which plots hedge fund equity holdings over time as a fraction of total market capitalization.

While hedge funds are known for holding both long and short positions, the information reported in the 13F filings includes only long transactions. To complement the long holding data, we use short interest data provided by the exchanges. These data are reported monthly since 1988 at the stock level (therefore we cannot identify the investors who hold the short positions). In our analysis we assume that most short sellers are arbitrageurs, and of those, many, if not most, are hedge funds. Our assumption is supported by the parallel increase in the aggregate short selling and hedge fund activities over time (compare Figures 1 and 2; the correlation of the quarterly changes is 0.38). Furthermore, aggregate short selling activity is quite small in magnitude, even in recent years, suggesting that only a small group of specialized arbitrageurs engage in it.

We employ several widely used datasets for stock-level and market-level information. Specifically, we use CRSP and Compustat for stock characteristics. We use two popular aggregate liquidity measures: Pastor and Stambaugh's (2003) innovations in liquidity and Acharya and Pedersen's innovations in illiquidity (2005; see also Acharya, Amihud, and Bharath 2009). Pastor and Stambaugh measure market-wide liquidity from the aggregation of firm-level OLS slopes of daily returns on signed daily trading volume within a month. Acharya and Pedersen capture aggregate illiquidity by averaging the stock-level illiquidity as measured by Amihud's (2002) ratio. Both liquidity factors are expressed at the quarterly frequency by summing monthly innovations. In addition, to contrast the effect of liquidity with that of aggregate uncertainty and returns in the equity market, we also consider the first difference in the end-of-quarter VIX index (VIX) and quarterly excess market returns (R_m–R_f). We change the

[14] See BusinessWeek's article "Hedge Your Bets like the Big Boys" by Tara Kalwarski, in the December 28, 2009 issue.

sign to the Acharya and Pedersen and VIX innovations so that an increase in these factors describes improvements in liquidity and reduction in uncertainty, respectively.

2.2. Summary Statistics

Because our analysis focuses on both long and short holdings and because the hedge fund universe in the 1980s is tiny relative to the explosion that occurred over the following two decades, we limit our hedge fund holdings and short interest data period to the third quarter of 1989 until the first quarter of 2009 (this period mostly overlaps with the period for which we have short interest data). In addition, we winsorize fund flows and changes in hedge fund equity holdings at the 5th and 95th percentiles within each quarter, as the distributions of these variables have fat tails. Finally, we verify that our results are not driven by extreme observations.

Table 1 presents summary statistics of the datasets used in the study. In Panel A we present the summary statistics of the aggregate stock market participation by hedge funds. The table shows that the selected hedge funds hold, over the two decades, 1.84% of the entire stock market capitalization on average, peaking at 3.75% (in the second quarter of 2007). The short interest ratio averages 1.75%, peaking at 3.77% (in the second quarter of 2008).

The dependent variables in the regressions in aggregate data are the change in hedge fund holdings as a percentage of total equity holdings (1.61% on average) and of total market capitalization (0.027% on average). To construct these variables we aggregate the quarterly trades made by each fund evaluated at previous period prices and divide them respectively by either the total equity holdings by hedge funds in the previous quarter or by the total market capitalization in the previous quarter. We first adjust shares held for split and other distributions. Then we use the quarterly holding snapshots to derive the trades and make sure that we are filtering out changes in holdings that originate from changes in the universe of 13F filers.[15] To this purpose, we require hedge funds to appear in two consecutive quarters. When a hedge fund does not report (since it is below the $100 million assets-under-discretion cutoff), we eliminate the observation (as opposed to reporting a large drop in holdings). The choice of previous-

[15] More details about the sample construction and trade derivation are available as a WRDS research application with the SAS code: "Institutional Trades, Flows, and Turnover Ratios using Thomson-Reuters 13F data," http://wrds-web.wharton.upenn.edu/wrds/support/Data/_004Research%20Applications/_003Research%20Guides/_000Files%20for%20Thomson%20Reuters%2013F%20Database%20Research%20Applications/institutional_trades.cfm

quarter prices allows us to focus on changes in equity holdings that are due to trades and not to price changes.

Panel B presents summary statistics for the stock-quarter-level sample. The dependent variable in the stock-level regressions is the change in the number of shares of a firm held by hedge funds aggregated across all hedge funds in our sample divided by total number of shares outstanding for that firm. Across stocks, this figure averages 0.07%. Focusing on the level of stock ownership, hedge funds hold about 3.0% of firm equity on average. From the comparison with the aggregate holdings in Panel A, which are weighted by market capitalization, it appears that hedge funds' equity holdings are tilted towards smaller stocks, consistent with the evidence in Griffin and Xu (2009). Volatility is computed as the standard deviation of monthly returns over a two-year window.

Panel C of Table 1 presents summary statistics for the hedge-fund-quarter-level data. The dependent variable in some of the hedge-fund-level analysis below is the fraction of the fund equity portfolio that is traded over the quarter. Again, the choice of previous-quarter prices avoids introducing a bias due to the change in prices over the quarter. To construct this variable we aggregate the quarterly changes in holdings for all the stocks in the fund portfolio and evaluate them at the previous quarter prices. Then, the total dollar value of the trades is divided by the lagged (previous quarter) value of the equity portfolio. The average percentage change in hedge funds' equity portfolios is 4.59%. The hedge-fund-quarter data is matched with TASS, as explained above. We use TASS data to construct total returns, by aggregating returns of funds within each management company (weighted by asset size). Then, we compute quarter t fund flows as the quarterly difference in assets under management minus the dollar return on quarter $t - 1$ assets. Fund flows are then scaled by the lagged hedge fund equity holdings. We also define a dummy for whether the fund holds put options on individual stocks according to the 13F filings (about 32% of the hedge-fund-quarter observations after 1999, on average). Then, we construct variables that capture the fraction of the firm's assets that are invested in the different strategies identified by TASS.

Panel D provides a summary of coverage for the 13F and TASS data as well as summary statistics about hedge funds' equity portfolios. It shows that, over time, more small hedge funds entered the industry but held, on average, fewer stocks at a higher (annualized) turnover rate. As

in Wermers (2000), Brunnermeier and Nagel (2004), and the CRSP mutual fund database, portfolio turnover is defined as the minimum of the absolute values of buys and sells during a quarter t divided by total holdings at the end of quarter $t-1$, where buys and sells are measured with end-of-quarter $t-1$ prices. This definition of turnover captures trading unrelated to inflows or outflows. Because it is computed from quarterly snapshots, it is understated; nevertheless it provides an important assessment of the relevance of quarterly holdings data. The average quarterly turnover in the sample is 27.2% (109% annualized). The magnitude of turnover in our data is comparable to that found by Brunnermeier and Nagel (2004). While somewhat higher than the 72.8% (annualized) turnover for mutual funds in 1994 found by Wermers (2000), our figure indicates that a substantial part of portfolio holdings survives on the quarterly horizon. As argued by Brunnermeier and Nagel, this finding legitimates the use of quarterly snapshots to capture the low frequency component of hedge fund trading. Also important for the purposes of our analysis, the high frequency turnover in portfolio composition is less of a concern than it has been for previous studies that used 13F data. Our focus is on aggregate changes in the allocation to equity in the hedge fund portfolio. Arguably, the asset allocation dimension of the portfolio is less likely to be affected by high frequency turnover than the stock selection dimension. Finally, a similar argument limits the problems arising from potential portfolio manipulation ahead of the filing date. While it is possible that fund managers reshuffle their stock holdings to conceal trading strategies, we find it is less likely that they alter the portfolio's overall exposure to the stock market.

2.3. Identifying Crises

For the analysis below, we need to identify periods of stress in the equity market. To this end, we select quarters of extreme realizations (two standard deviations from the mean) of four different market condition variables. The Pastor and Stambaugh (2003, PS hereafter) and Acharya and Pedersen (2005, AP hereafter) variables are based on direct measures of market liquidity. The PS and AP variables are available from the last quarter of 1989 to the last quarter of 2008. However, because the 2008 events cause major skewness in the AP variable which would obfuscate other liquidity events in the sample, we use only the realizations of this variable in the 1989:Q1-2007:Q4 period to identify financial crises. The evidence for the 2008 crisis is then presented separately.

We also use other measures for alternative dimensions of market stress. Nagel (2009) suggests that the returns to providing liquidity increase in periods of aggregate uncertainty, as captured by the VIX index. In this spirit, we use quarterly changes in the (negative of the) VIX index as a further variable, which is available over the entire sample. Finally, the return on the stock market in excess of the risk free rate captures stock market crises R_m–R_f. Because of our normalization, for all the variables, low variable values reflect poor market conditions. The correlations (Panel E) among the liquidity variables and between the liquidity variables and the VIX and the market variable are surprising low. The correlation between the VIX and the market variable is high (0.71).

Panel F presents the list of identified crises, per market condition variable. We notice that based on the definition of a crisis quarter as being two standard deviations away from the mean over the period, crisis quarters are not entirely overlapping across market condition variables.

3. Hedge Fund Trading during Liquidity Crises

3.1. Aggregate Equity Market Participation of Hedge Funds

3.1.1. Aggregate Long Hedge Fund Holdings

Our first goal is to characterize hedge fund behavior during crises. In Figure 1, we look at aggregate hedge fund equity holdings as a fraction of total stock market capitalization. The vertical lines in the figure denote our selection of events of potential market stress since 1990 (e.g., Summer 1998, September 2001, the period after Summer 2007, etc.; the full list is provided in the appendix). The figure seems to suggest that in times of crisis, hedge funds withdraw from the market, especially in 2008. Of course, this evidence is affected by the relative changes in market prices, which confound the pure effect of trading. For this reason, in the remainder we focus directly on actual hedge fund trades.

Next, we use regression analysis to examine the relation between changes in hedge fund holdings of stocks and the four aggregate market condition variables described in Section 2. The results of the time-series analysis are presented in Table 2, Panel A. The dependent variable is the quarter-on-quarter aggregate change in hedge fund equity holdings, and the explanatory variables include indicators for the changes in the examined market condition variables, and controls for market returns (also as indicators of standard deviations from the population mean).

Given the design of the regressions, the coefficients measure the average quarterly change in aggregate equity holdings by hedge funds. The coefficients on the liquidity variables indicators (Columns (1) and (2)) show that, controlling for market returns, hedge funds decrease their equity participation almost monotonically, yet non-linearly, as market liquidity decreases. In particular, hedge funds reduce their participation considerably when liquidity variables are low.[16] The regressions show hedge funds reduce their equity participation by an average of 10% in quarters in which either the PS factor or the AP factor was two standard deviations below the mean. Interestingly, Columns (3) and (4), where crises are defined by the VIX and market excess returns, are statistically insignificant and economically weak. Comparing the coefficients in Columns (1) and (2) to those in Columns (3) and (4) suggests that hedge funds behavior is associated with illiquidity rather than simply with uncertainty or poor market returns.

We have a particular interest in quantifying the withdrawal of hedge funds from the equity market during the crisis of 2008. In Column (5), we add an indicator for the third and fourth quarters of 2008, which are likely to capture the time of most severe stress in 2008 due to the collapse of Lehman Brothers. The results show that during the last two quarters of 2008, hedge funds exited the equity market at a dramatic rate of 16.4% per quarter on average.

In Panel B of Table 2, we explore whether hedge funds' exit from the equity market is only contemporaneous or whether some effects show up with a lag or lead. We regress changes in hedge fund ownership on current, lagged, and lead crisis indicators, as well as on corresponding indicators for market returns. The results show that the exit of hedge funds is primarily contemporaneous with respect to liquidity crises.

To help assess the systemic impact of the exit of hedge funds from the equity market, we repeat the analyses of Panels A and B where we measure the change in hedge fund holdings as a percentage of the total market capitalization (in lagged quarter valuations). The results are presented in Table 2, Panels C and D. The panels show that in quarters of low aggregate liquidity, hedge funds sell stocks worth 0.22% of the total market capitalization (Column (1)). During the financial crisis of 2008, hedge funds sold stocks worth 0.6% of the total market capitalization at each of the third and fourth quarters of 2008.

[16] The results are almost identical when we restrict the data to the sample of hedge funds that self-report to TASS.

Because pure-play hedge funds, which are examined here, hold only a small fraction of the market capitalization, their selling pressure appears to be small in magnitude relative to the total market capitalization. It is hard to draw implications on the price impact of these trades without an equilibrium model of the market. In particular, one needs to take in consideration the liquidity of the market and the informativeness of the trades. A study of the effect of the observed trades on market prices is therefore beyond the scope of this work. It is worth pointing out, however, that the measured changes in hedge fund portfolios have the potential to be disruptive. In Brunnermeier and Pedersen (2009), when arbitrageurs are constrained in their liquidity provision, the equilibrium is fragile. That is to say, small shocks to the net supply of assets can cause drastic price changes. Also important, the observed selloffs can be concentrated in a few illiquid assets, which are more likely to be held by arbitrageurs in normal times. This behavior is denoted as a flight to quality. In such a case, the losses in hedge fund capital, and the consequent drop in liquidity provision, are likely to be more relevant than the impact on a well-diversified portfolio. To further investigate this channel, in Section 4, we study the stock-level cross-sectional dimension of selloffs.

3.1.2. Aggregate Short Interest

The consumption of liquidity that is likely caused by the observed selloffs can be mitigated if hedge funds close short equity positions at the same time as they sell stocks. Brunnermeier and Pedersen (2009) clearly show that the limits to arbitrage can constrain speculators' positions on the short side as well as on the long side. So, we need to show that the unwinding of short positions, if it occurs, does not overlap with the stock selloffs that we have documented so far. Because we do not observe hedge funds' short positions, we proceed by assuming that the short interest reported by the exchanges is largely driven by hedge funds.

In Table 3, Panel A, we regress the change in the value-weighted aggregate short interest on market condition dummies. In all the regressions, the omitted category is normal market condition (within one standard deviation around zero). For the PS liquidity factor (Column (1)), short interest declines significantly (both statistically and economically) in moderate declines in market liquidity. In liquidity crises, the coefficient is negative, but statistically insignificant (t = -0.9). The AP liquidity index (Column (2)) produces declines in short interest in both very high and very low liquidity states. The magnitude of declines in short interest in Columns (1) and (2)

are around 0.2%; this is a significant amount given that the average (median) short interest is 1.75% (1.65%) in our sample period. For the VIX and market returns (Columns (3) and (4)), we do not find any special pattern except for an increase in short interest following moderate market declines. Importantly, the decline in the short interest in the crisis of 2008 (Column (8)) explains the drop in short interest during liquidity crises, based on the PS index (Column (1)). In each quarter of the 2008 crisis, aggregate short interest declined by 0.5%. Note, however, that this result does not explain the AP results in Column (2), as this series discontinues before the crisis of 2008. Overall, consistent with the effect of tighter margin requirements on short positions (Brunnermeier and Pedersen, 2009), we find a significant reduction of short interest during liquidity crises.

In Panel B of Table 3 we explore whether there are lag or lead effects in the behavior of short selling around crises. Interestingly, we find that short selling increases dramatically ahead of liquidity crises (Columns (1) and (2)). This evidence suggests that short sellers can anticipate (or, perhaps, propagate) liquidity crises. We do not observe similar evidence around periods of increases in aggregate uncertainty (Column (3)) or stock market crashes (Column (4)).

As argued above, an important issue is whether short sellers provide liquidity in the process of unwinding short positions during liquidity crises. If indeed a large fraction of short sellers are hedge funds and they unwind short positions on the same stocks that they sell, then the net effect on the liquidity of these stocks may be limited. The reason is that unwinding short positions involves buying shares, which effectively enhances liquidity in times of liquidity crises.

To rule out this possibility, we resort to stock-quarter level analysis. We study the relation between stock-level changes in hedge fund holdings and changes in short interest. In Table 3, Panel C, we regress stock-quarter changes in hedge fund ownership on changes in stock-quarter level of short interest and interaction with the crisis dummy. We find that the correlation between hedge fund trading and short selling is positive and statistically significant, however, the coefficient is low: around 10% across specifications. The correlation does not materially change during crises periods. Results do not change when we include stock fixed effects (not reported). To illustrate the economic magnitude, if there is a 1% decline in short interest, hedge funds holdings decrease by 0.1%. Hence, only 10% of the liquidity consumption by hedge funds is compensated by liquidity provision from the unwinding of short positions.

These results suggest that liquidity consumption by hedge fund withdrawals and liquidity provision from short position unwinding largely occur in non-overlapping sets of stocks.

3.2. The Distribution of Hedge Fund Trades

Given the large selling on the part of the aggregate hedge fund sector during liquidity crises, it is important to understand whether the effect is driven by large sales on the part of a few hedge funds, while the rest of the sector continues to provide liquidity. In particular, if a large fraction of hedge funds were increasing their market exposure to counteract the selling pressure, the concerns for aggregate liquidity would be less severe.

To explore this issue, we compute for each hedge fund the fraction of equity bought or sold at previous-quarter prices. We begin by comparing the distributions of hedge fund trades in Figures 3a and 3b. Figure 3a presents the unconditional distribution of hedge fund trades and the distribution of trades conditional on a state of crisis as measured by the PS index. Figure 3b shows that same unconditional distribution and the distribution of hedge fund trades in the second half of 2008. Both charts show that there is a shift to the left in the distribution of trades during a crisis and a non-negligible mass of hedge funds sell significant portions of their portfolios. This pattern is particularly noticeable for the crisis of 2008. In Figure 3a, there is no evidence that funds exploit crises to increase their holdings. While Figure 3b shows that in the crisis of 2008 about 5% of hedge funds increase their portfolio holdings by more than 90%, it turns out that these are primarily small funds (see below).

We examine these issues also in Table 4, Panels A and B. In Panel A, we present the distribution of funds with respect to the degree of their buying or selling, and the liquidity state measured by the PS variable. The table shows that while the distribution of hedge funds that buy any amounts, or sell moderate amounts, is more or less stable across liquidity states, the distribution becomes skewed for large sellers in extreme events. During normal times ($-\sigma \leq PS < \sigma$) about 9% of the funds sell between 20% and 40% of their portfolios within one quarter, and 6% of the funds sell more than 40% of their equity portfolio in a given quarter. Conversely, during times of crisis, these numbers increase to 12.6%and 13.6%, respectively. When we isolate the recent crisis of 2008 in the last column, the numbers are staggering. We find that 18.8% of hedge funds sold between 20% and 40% of their portfolios in each quarter, and that an average of 23.4% of funds sold more than 40% of their equity holdings in each quarter of the crisis.

We are also interested in assessing the relative size of the funds behind the observed trades. If the buying funds in a crisis are relatively large, one can hope that the impact on aggregate liquidity of the observed trades is less severe, because large funds have deeper pockets and can more solidly lean against the wind. In Panel B of Table 4, we repeat the analysis of Panel A, while value-weighting the funds in each bucket using the total lagged equity portfolio value. The panel shows that the distribution of massive sellers at illiquid times does not change much, indicating that selloffs are performed by hedge funds that are representative of the hedge fund size distribution. However, the distribution of massive buyers shrinks, suggesting that massive buyers are small hedge funds.

Overall, the results on the distribution of trades corroborate the impression that hedge funds do not make a positive contribution to aggregate liquidity during crises. The shift in the distribution of trades towards large sales in a crisis is important in general, and is especially pronounced in 2008. There is scarce evidence that the selling pressure is counterbalanced by increased buying on the part of other funds. Also, the funds that expand their portfolios are primarily small and are likely unable to make a difference in terms of liquidity provision.

3.3. Who Provides Liquidity during Financial Crises?

Since hedge funds reduce their positions in equity during times of low market liquidity, it is interesting to find out who buys their shares. In other words, we would like to see whether one can identify another type of investors who are the liquidity provider during financial crises.

In Table 5, we repeat the regression from Table 2, Panel A, for other types of investors: mutual funds, other institutions, and retail investors (including management). The holdings of mutual funds and other institutions are also identified using the 13F filings. For each stock, we determine the fraction of the holdings of retail investors as the complement to one of the fraction held by institutional investors that file the 13F.[17]

We choose to focus on the PS index as the liquidity index. For mutual funds (Columns (1) and (2)), there is a decrease in holdings in moderate declines in liquidity, however, there is no effect in a liquidity crisis, including the crisis of 2008. Instead, although slightly below the

[17] This method of imputing retail investors' holdings provides an upper bound. The reason is that 13F filings do not include institutions that do not make the $100 million threshold. However, given the small size of the excluded institutions, we believe the approximation error to be modest.

threshold of statistical significance, it appears that other institutions (Columns (3) and (4)) are net buyers during financial crises. This is not true, however, for the 2008 crisis. In 2008, it seems that retail investors increased their net exposure to the market by about 1.35% (t = 0.935). This roughly corresponds to the amount that hedge funds sold over that period, although statistically insignificant. The average effect for these two is not statistically significant. However, in non-tabulated results, we find that retail investors significantly increased their market exposure in the third quarter of 2008 by 3.4% of market capitalization (t = 1.8), while their holdings remained virtually unchanged in the fourth quarter, when the market fell even further.

To summarize, it appears that other, non-mutual fund, institutional investors provide liquidity during crises. Given the details of our data, we can only conjecture that this role is played by broker-dealers or by institutions with a long investment horizon, such as pension funds. The 2008 crisis represents an exception, as at the time retail investors ended up absorbing the stocks sold by hedge funds. This situation is perhaps better characterized as a manifestation of poor market-timing skills on the part of retail investors relative to hedge funds than a deliberate liquidity provision by this sector of investors. Indeed, retail investors increased their exposure in the third quarter of 2008, before the further deterioration in market conditions that occurred later in the year and at the beginning of 2009.

4. The Determinants of Hedge Fund Selloffs

So far, we have documented large selling by hedge funds during periods of low market liquidity. There are two non-mutually exclusive explanations for this phenomenon.

First, investors and lenders could force hedge funds to liquidate equity positions by tightening their funding. This channel characterizes the limits-of-arbitrage theories: hedge funds cannot exploit market mispricing and monetize the illiquidity premium because their capital is cut off (as in Shleifer and Vishny, 1997). We test this explanation by examining the effect of investor fund flows on hedge fund trades during liquidity crises. Also, we explore whether highly leveraged hedge funds are more likely to sell equities. Finally, we look for evidence of flights to quality by focusing on trades of high-volatility stocks.

Second, it is possible that equity selloffs by hedge funds during financial crises are evidence of their liquidity provision in other, potentially less liquid, markets. In other words, hedge funds could sell equity during liquidity crises as part of portfolio reallocation across asset

markets, as they identify better opportunities in non-equity markets. To assess this possibility, we infer whether hedge fund managers have a negative outlook on the stock market by examining whether there is a correlation between put option holdings and selloffs during crisis periods. Further, we study the styles of hedge funds that exit the equity market during a liquidity crisis. Finally, we analyze the future returns on the non-equity part of the portfolios of the hedge funds that exit the stock market during a crisis.

4.1. Financial Constraints

4.1.1. Redemptions by Investors

We conjecture that investor redemptions drive some of the selling by hedge funds. Redemptions may be at their peak during periods of market illiquidity, and may force hedge funds to sell relatively liquid assets, such as stocks. We explore this idea by analyzing the cross-section of hedge funds' quarterly trades. The prediction is that hedge funds that experience larger redemptions would sell more equity. We impute net fund flow data[18] (scaled by lagged equity portfolio size) from TASS, and thus need to restrict the 13F dataset to the sample matched with TASS. We also consider two quarterly leads of fund flows, because redemptions are often known in advance due to the redemption notice that clients must give to the fund. Even if the redemptions are not known in advance, fund managers in poor performing funds could rationally anticipate future redemptions based on the existence of a positive flow-performance relation (see, e.g., Agarwal, Daniel, and Naik, 2006).

We present the results in Table 6, which explores how well the different variables explain the change in quarterly equity holdings by hedge funds. In all regressions, we add controls for fund returns in the past twelve months and the log of the size of the equity portfolio at the end of the previous quarter to absorb potentially confounding effects. Standard errors are clustered at the calendar quarter level. Panel A of Table 6 focuses on the PS liquidity index (Columns (1) to (10)), and on the 2008 crisis (Column (11)). In Column (1), we present the baseline regression.

[18] Net fund flows are computed as TASS variables EstimatedAssets(q) - EstimatedAssets(q-1)(1 + RateOfReturn), scaled by lagged (q-1) equity portfolio size which is derived from 13F. EstimatedAssets are aggregated from the fund/style level to the management company level. RateOfReturns are weighted by the estimated assets.

We use the universe of firms that appear both in TASS and 13F,[19] and regress the changes in their equity holdings on the crisis indicator and on hedge fund controls (size and past returns). We note that based on this sample, hedge funds reduce their equity portfolio by 6.2% per quarter on average during liquidity crises. In Column (2), we introduce fund flow variables as well as interactions of the crisis dummy with current and lead fund flows. The regression shows that flows are positive and statistically significant, while the coefficients on the interactions with the crisis dummy are statistically insignificant. Yet, introducing these variables reduced the coefficient on the crisis indicator from 6.2% to 5.0%, a decline of 19%. Thus hedge funds liquidate their equity positions due to current and future flows. We focus on the effect of fund flows in the crisis of 2008 (Column (11)). The results show that contemporaneous flows are negatively correlated with hedge fund trading, while future fund flows are positively correlated with trading, suggesting that hedge fund trading during the crisis was driven to some extent by future investor redemptions.

Panels B, C, and D repeat the regressions in Panel A for the Acharya-Pedersen liquidity index, the VIX, and market excess returns, respectively. The results in Panel B are qualitatively similar and stronger in magnitude relative to the results in Panel A. In Column (2), the coefficient on fund flows is positive and reduces the magnitude of the coefficient of the crisis indicator from 6.8% to 4.1%, a decline of 40%. The regressions in Panel B that use the VIX as a crisis indicator show no sensitivity to investor redemptions around crisis events. The regressions in Panel D, where crisis is defined based on market returns, exhibit a significant relation to investor redemptions.

4.1.2. Credit Tightening by Lenders

Next, we look for evidence that hedge funds sell their equity positions because they are forced to do so by lenders, as suggested by the limits-to-arbitrage theories. We conjecture that higher leverage makes a fund more exposed to the threat of margin calls. Hence, in our first test we examine whether highly leveraged funds sell larger portions of their portfolios during liquidity crises. In Column (4) of Table 6, Panel A, we regress the fraction of the equity portfolio traded by hedge funds over the quarter on the crisis indicator (based on the PS index) interacted

[19] Since the regressions in Table 6 are used as a benchmark across different explanations, we restrict the sample used to a 1999 start, when put option data is available. The results do not change materially if we begin the sample earlier.

with hedge funds' average leverage.[20] The resulting coefficient on the interaction is negative and statistically significant, suggesting that highly leveraged hedge funds are more likely to reduce their equity holdings during a crisis. Average leverage is measured as debt over investor equity. The size of the coefficient is -4.7% and should be multiplied with the leverage in order to get the economic effect. A 2:1 leveraged hedge fund sells 5.9%[21] more of its equity portfolio than an unleveraged fund during a liquidity crisis. By comparing the slope on the crisis dummy in Column (4) (-5.2%) with the same coefficient in the base specification in the sample of funds with available leverage (Column (3)) (-3.9%), we conclude that leverage explains about 41% of the sales during a crisis. The effect of leverage is weaker in magnitude and insignificant in the crisis of 2008 (Column (11)). When using Acharya-Pedersen as a liquidity indicator, the results are similar (Panel B). When a crisis dummy is measured as extreme changes in the VIX or market returns, there is no material effect of hedge fund leverage (Column (4) of Panels C and D).[22]

We also assess the total variation in hedge fund equity trading that can be explained by financial constraints (that is, redemptions and leverage combined). In Table 6, Panel A, Column (5), we regress the changes in equity holdings on the crisis indicator interacted with both net fund flows variables and average leverage. The main effects are also included. By comparing the coefficient on the crisis dummy to the coefficient in Column (3), we conclude that financing constraints account for about 56% of stock sales by hedge funds during a liquidity crisis. In Panel B, where the AP index is used, the ratio of the coefficients points to the conclusion that financial constraints account for about 65% of the variation.

In the second set of tests, we explore the cross-section of stocks and examine whether hedge funds are more likely to close positions in high volatility stocks during liquidity crises. We focus on return volatility because it is positively correlated with stock margin requirements. Drawing on Brunnermeier and Pedersen (2009), we conjecture that at times of low liquidity,

[20] The Average Leverage variable is a cross-sectional variable provided by TASS. This variable describes the general level of leverage of hedge funds, reported by funds' managers. Like other variables from TASS, we aggregate this variable from the fund level to the management company level, weighting it by EstimatedAssets.

[21] 2 * (-4.720% + 1.825%) = -5.790%

[22] Since about 53% of the TASS hedge funds report an average leverage of zero, we repeat the test for the population that has non-zero average leverage. The coefficient on the interaction between the crisis dummy and average leverage changes to -5.953% (t = -3.3) and -5.790% (t = -4.5) in Panels A and B, respectively.

hedge funds enact a flight to quality. That is to say that when they are forced by lenders to liquidate their positions, hedge funds may choose to sell high volatility stocks first because of their higher margin requirements. Hedge funds may be motivated to sell high volatility stocks for the sake of internal risk management as well, as suggested by Vayanos (2004). Specifically, hedge funds (like their capital providers) use value-at-risk (VaR) models as a tool to monitor risk exposure. Reducing risk exposure could be vital in preempting future redemptions and margin calls. In our tests, we cannot separate these two explanations as they are observationally equivalent with regard to the prediction of flights to quality.[23]

In Table 7, we test whether stocks with higher volatility are more heavily sold by hedge funds during crises. We use stock-quarter level data. The dependent variable is the change in hedge fund share holdings as a percentage out of the lagged total shares outstanding. The explanatory variable of interest is the stock level volatility indicator (indicating above–the-median volatility at the end of the preceding quarter) interacted with crises indicators. If hedge funds reduce their holdings more in high volatility stocks during extreme episodes, then the expected interaction coefficient is negative. In all regressions, standard errors are clustered at the quarter level. The results in Table 7, Panel A, Columns (1) and (2), confirm this prediction: hedge funds are more likely to reduce their positions in high volatility stocks during periods of low aggregate market liquidity. In Column (1), high volatility stocks have almost twice the likelihood of being sold by hedge funds during a liquidity crisis than do low volatility stocks. Column (2) produces a lower estimate: the likelihood of selling high volatility stocks during a liquidity crisis is about 50% higher than that of selling low volatility stocks. Column (3) shows that market uncertainty, as measured by the VIX, does not affect the likelihood of selling stocks with respect to volatility. Interestingly, Column (4) presents evidence that the likelihood of selling high volatility stocks in periods of low market returns is only slightly (and statistically insignificantly) higher than that of low volatility stocks. Finally, Column (5) shows that during the crisis of 2008, hedge funds reduced their positions more in high volatility stocks.

[23] We note, however, that the distinction between internal and external forces is blurred. Consider the external pressure that lenders and investors may put on hedge funds to liquidate high volatility stock positions. Since hedge funds can anticipate the demands of risk reduction by external capital providers, they can respond ahead of time by liquidating high volatility positions. Hence, hedge funds' reduction of risk according to VaR models can be viewed as an attempt to preempt forced liquidation.

We repeat the analyses for changes in stock-level short interest. The motivation for this analysis is twofold. First, we recognize that that portfolio volatility can also be reduced by closing short interest positions. Second, we are interested to verify that hedge funds do not reduce their high volatility long positions because they are bearish on high volatility stocks. If the limits-to-arbitrage forces are at play, then we anticipate similar results in the short interest sample, i.e., that hedge funds more aggressively reduce positions in high volatility stocks.

The evidence in Panel B validates this prediction. Columns (1) and (2) show that during liquidity crises, stock-level short interest of high volatility stocks is reduced by a greater amount (measured as change in the short interest, as a fraction of market capitalization at previous-quarter end) than the short interest of low volatility stocks. Column (3) shows that during periods of high market uncertainty as measured by the VIX, short sellers reduce their overall positions, albeit less than for high volatility stocks. Column (4) presents evidence that during periods of low market returns, arbitrageurs close short positions (realizing profits), particularly for high volatility stocks.

To summarize, we find strong support for the hypothesis that sales of stocks by hedge funds during crises are motivated by financial constraints. These can take the form of redemptions, margin calls, and risk management models. The combined effect of these forces explains on average 60% of hedge fund stock selloffs during liquidity crises. In order to explain the remaining fraction of stock sales, we next examine the hypothesis that hedge funds deliberately sell equity in pursuit of higher expected returns from other assets.

4.2. Reallocation of Capital to Other Assets

The results in Section 4.1 suggest that limits to arbitrage play a first-order role in explaining the decrease in equity holdings during a crisis. Next, we explore the other motive of hedge funds to reduce their equity holdings: hedge funds may find it optimal to invest in other, more profitable, asset markets. After all, negative shocks are usually correlated across asset markets and a more sizable illiquidity premium can be earned in markets that are typically more illiquid than the equity market. If we find evidence for this channel, then we can conclude that, in spite of their capital constraints, hedge funds do provide liquidity in an illiquid (non-equity) market.

Ideally, we would like to test directly whether hedge funds increase their non-equity portfolio. However, combining the TASS and 13F datasets does not allow for the reconstruction of hedge funds' balance sheets. Although in our data we have the size of the equity portfolio (from the 13F dataset), the size of assets under management (from TASS) and the average leverage (from TASS), the average leverage variable in TASS provides a snapshot at the time of reporting. That is, leverage does not have a time-series dimension.

Hence, we are obliged to resort to alternative tests. We first assess whether hedge fund managers expect negative returns from the stock market by exploring whether they have defensive portfolio holdings. Then, we study which types (styles) of funds exit the stock market during liquidity crises. We conjecture that, if stock sales are motivated by the pursuit of higher returns in other markets, funds with multi-asset expertise are more likely to exit than equity-specialized hedge funds. Finally, we test whether funds that sell more equity during crises earn higher returns on the rest of their portfolios in the next quarters. This would be supporting evidence for the conjecture that they earn a reward from providing liquidity to other markets.

4.2.1. Negative Outlook

It is reasonable to believe that hedge funds exit the equity market towards other markets if they expect negative returns from equity. We proxy for bearish views about the equity market by measuring defensive positions. Specifically, using 13F data, we create an indicator variable for whether the fund holds any put option on U.S. stocks. We conjecture that funds that hold put options during a crisis are more likely to sell stocks, as a consequence of their negative outlook on equity.

In Table 6, Panel A, Column (7), we interact the PS crisis dummy with an indicator of whether hedge funds hold equity put options. The magnitude of the combined coefficients on this interaction and the main effects is -5.5%, suggesting that hedge funds that hold put options during a crisis sell larger portions of their equity portfolios by this amount. By comparing the slope on the crisis dummy in Column (7) and Column (6), which contains the base specification, we infer that, in this sample of funds, the negative outlook hypothesis explains about 27% of stock sales during a crisis.

In the corresponding regression in Table 6, Panel B, Column (7), which is based on the AP index, the magnitude of the coefficients is similar. Interestingly, there is no relation between

hedge fund selling and put positions following crises based on uncertainty (VIX; see Table 6, Panel C, Column (7)). Following stock market crashes, however, hedge funds' equity trading is positively correlated with put options holding.

Finally, in Columns (8) to (10), we examine the combined effect of financial constraints (redemptions and leverage) and put options for the sample of funds in which all the relevant variables are available. From Panels A and B, we infer that the two channels together bring the slope on the crisis dummy to virtually zero. This evidence suggests that while financial constraints play the main role in explaining selloffs, one also needs to take voluntary portfolio reallocation into account in order to get a detailed description of hedge fund selloffs in liquidity crises.

4.2.2. The Styles of the Funds That Exit

Next, we explore the types of hedge funds that sell stocks during crises. We conjecture that hedge funds with multi-asset styles have a higher likelihood of selling because they seek investment opportunities in other markets. Because we want to identify sales that are not forced by investors, in one specification, we control for current and future fund flows.

Because TASS reports investment styles per fund, and because our analysis is performed at the hedge fund parent company level, we aggregate fund styles at the company level, and weight them by the lagged total assets managed by each fund. Thus, each hedge fund company can have multiple styles, each accounts for 0% to 100%, and all add up to 100%. In other words, the style variables capture the weight of a given style in the total assets that are managed by the funds in the same company.

In Table 8, the dependent variable is the percentage change in hedge funds' equity portfolios. The standard errors are clustered at the calendar quarter level. We add controls for fund returns in the past twelve months and the log of the equity portfolio at the end of the previous quarter to absorb potentially confounding effects. For each aggregate factor, the first specifications (Columns (1), (3), (5), and (7)) include interactions between the style variables and the crisis dummy. The main effects of the styles are also included along with a constant. We do not include the crisis dummy alone because of perfect collinearity, given that the styles add up to one. Across factors, the styles that sell equity more significantly during a crisis are: managed futures, global macro, multi-strategy, emerging markets, fund of funds, and event driven. As the

investment focus of these styles spans different assets, this evidence corroborates the conjecture that sales of U.S. equity are also determined by the search of opportunities in different markets.

In contrast, we find that the market neutral style increases significantly its long exposure to stocks. Given the long-short strategy of this style, we should infer that these funds also increase their short positions in stocks. Hence, one cannot conclude that these funds are net liquidity providers in the equity market during a crisis.

In Columns (2), (4), (6), and (8), we replicate the analysis by adding controls for fund flows. The goal is to isolate the trades that are not forced by investor redemptions. While the magnitudes on the interactions are slightly smaller, suggesting that part of the sales are due to redemptions, the main conclusions about the styles that sell during crises remain unaffected.

Overall, these results provide support to the hypothesis that sales of stocks during crises also occur because some funds, specifically those following multi-asset styles, reallocate their portfolio to other markets as investment opportunities arise.

4.2.3. Non-Equity Portfolio Returns

Finally, we examine whether hedge funds that exit the equity market during a crisis earn higher returns afterwards. Such finding would present additional evidence that hedge funds that leave the stock market use the proceeds to invest in other opportunities with higher expected returns.

TASS provides total portfolio returns at the fund level. We value-weight the fund level returns at the management company level using lagged fund assets and label them "total returns". This is the dependent variable in our regressions. Using 13F filings, we construct equity returns by assuming that trades occur at quarter-end prices. Our goal is to test whether funds earn high returns in other markets after selling equity during a crisis. Hence, in order to isolate the return on the non-equity part of the portfolio, in our regressions we control for the return on the equity portfolio return. This approach is subject to some caveats which we discuss below.

In Table 9 the dependent variable is future total returns (one and two quarters after the crisis), while the main explanatory variable is the interaction of the crisis indicator and a variable for negative changes in equity holdings (min(ΔEquity portfolio,0)). We also include the interaction of positive changes in equity portfolio and the main effects. Finally, we control for

contemporaneous and future fund flows, fund returns in the past twelve months, and the log of the equity portfolio at the end of the previous quarter to absorb potentially confounding effects. The standard errors are clustered at the quarter level. When focusing on the first quarter after a crisis (Columns (1) to (4)), there is no significant effect on future returns for funds that sell during the crisis.[24] More interesting, two quarters after a liquidity crisis, exiting hedge funds perform better than their peers on the non-equity part of their portfolio (Columns (5) and (6)). Notice that a negative slope on the interaction between crisis and sales denotes higher returns because the sales variable takes negative values. The economic magnitude is significant. Hedge funds that sell 20% of their equity portfolios have returns that are higher by 1.6% to 2.5% in the second quarter following the crisis.[25]

Incidentally, the coefficient on the equity portfolio return is strongly significantly related to total returns in all specifications. This evidence highlights the tight link between the changes in quarter-end 13F holdings and actual trades, which in turn generate returns. For this reason, it provides implicit support for our empirical methodology that hinges on quarterly snapshots of portfolio holdings.

Our attempt at isolating the return on the non-equity part of the portfolio relies on the implicit assumption that the relation between equity-portfolio returns and the total return is the same across funds. In other words, we estimate a unique slope on the equity return variable across funds, while different funds may very well have different splits between equities and other assets, including short positions. We cannot directly address this issue because we only observe long equity positions. However, we can mitigate this concern by letting the slope on equity returns vary for funds with different styles. The hope is that styles can help to control the across-fund difference in asset allocation. In an untabulated analysis, we add interactions of the equity portfolio returns with style indicators. The effect of interest, the slope on the interaction between sales and the crisis indicator, remains virtually unchanged. This evidence gives us additional confidence on the validity of our identification strategy.

[24] Incidentally, Column (4) suggests that funds that buy equity during market crashes also earn higher returns on the non-equity part of the portfolio, possibly consistent with the correlation of market-timing skills across assets.

[25] In Column (5): -20 * -0.111 + (-20) * 0.031 = 1.6. In Column (6): -20 * -0.149 + (-20) * 0.026 = 2.46.

Overall, the results in Table 9 suggest that hedge funds that exit the equity market during crises invest the proceeds successfully in other markets. Crisis events, as identified by our factors, were often characterized by the contemporaneous deterioration of liquidity for different asset classes. Hence, the last set of results is consistent with the conjecture that a motive for hedge fund equity selloffs during crises is the prospect of earning a premium from providing liquidity to other markets.

5. Conclusion

The question of whether limits to arbitrage constrain arbitrageurs is a fundamental issue in understanding how financial markets work. In this paper, we present new evidence about the behavior of hedge funds during liquidity crises. Hedge funds are the investor class most closely associated with arbitrage activity, and liquidity crises are the period in which arbitrage activity is the most costly.

Consistent with the presence of limits to arbitrage, we present evidence showing that hedge funds exit the equity market during liquidity crises. The magnitude of the effect is large. During the worst liquidity crisis in our sample, the crisis of 2008, hedge funds reduced their positions by 18% per quarter, over two quarters, which corresponds to about 0.5% of market capitalization per quarter. We do not intend to draw a causal link from hedge fund stock sales to the deterioration of market conditions. Our goal is solely to document on which side of the market hedge funds stand when aggregate liquidity dries up. From our analysis, one can conclude that, contrary to providing liquidity to the stock market, the aggregate hedge fund sector contracts its exposure to equity in bad times.

Also consistent with the limits to arbitrage, our results suggest that the majority of the selloffs during liquidity crises are related to capital withdrawals by investors and lenders. Furthermore, during crises, hedge funds more intensely close their positions (both long and short) in high volatility stocks. This finding supports the flight-to-quality predictions of the theories that postulate financial constraints for arbitrageurs.

However, limits to arbitrage likely do not tell the whole story behind hedge fund selloffs during financial crises. Stock sales by hedge funds also occur as a deliberate portfolio reallocation strategy in pursuit of a better risk-expected return tradeoff. Consistent with this view, we find that hedge funds that are net sellers of stocks are more likely to take defensive

positions in equity put options, indicating their negative outlook about future returns in the stock market. Furthermore, based on their styles, we infer that the selling hedge funds are likely to have access to and knowledge about other markets. Finally, the hedge funds that exit the stock market during liquidity crises exhibit significantly higher returns in later periods on the non-equity part of their portfolios, suggesting that they invest in other, potentially more illiquid, markets.

To summarize, our main conclusion is that liquidity provision in the stock market by hedge funds is drastically decreased during liquidity crises. While we do not rule out the possibility that some of the stock sales by hedge funds are motivated by the deliberate reallocation of capital to less liquid assets, the more important channel seems to be limits to arbitrage, in the form of investor and lender redemptions. Our findings strongly resonate with theoretical arguments that postulate pro-cyclical liquidity provision by arbitrageurs (Brunnermeier and Pedersen, 2009). From the point of view of regulators and policy makers that are concerned about systemic risk, our results about hedge funds compound with the evidence that other important actors in financial markets, namely broker-dealers, provide liquidity in a pro-cyclical manner (Adrian and Shin, 2009). Overall, the "shadow banking system" seems to behave in a way that amplifies negative shocks to financial markets.

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Appendix

List of Liquidity Events (for Figures 1 and 2):

1. Iraq Invasion of Kuwait - 08/1990
2. Asian Crisis - 4/1997 and 12/1997
3. Russian Default and LTCM Crisis - 6/1998 and 10/1998
4. Internet Stocks Crisis - 03-04/2000
5. 9/11 Terrorist Attacks - 09/2001
6. Market Confidence Crisis - 09-10/2002
7. Quant Liquidity Shock - 08/2007
8. Bear Stearns' Collapse - 03/2008
9. Lehman Brothers' Bankruptcy - 09/2008

Figure 1. Time Series Hedge Funds Holdings (% of Total Market Capitalization)

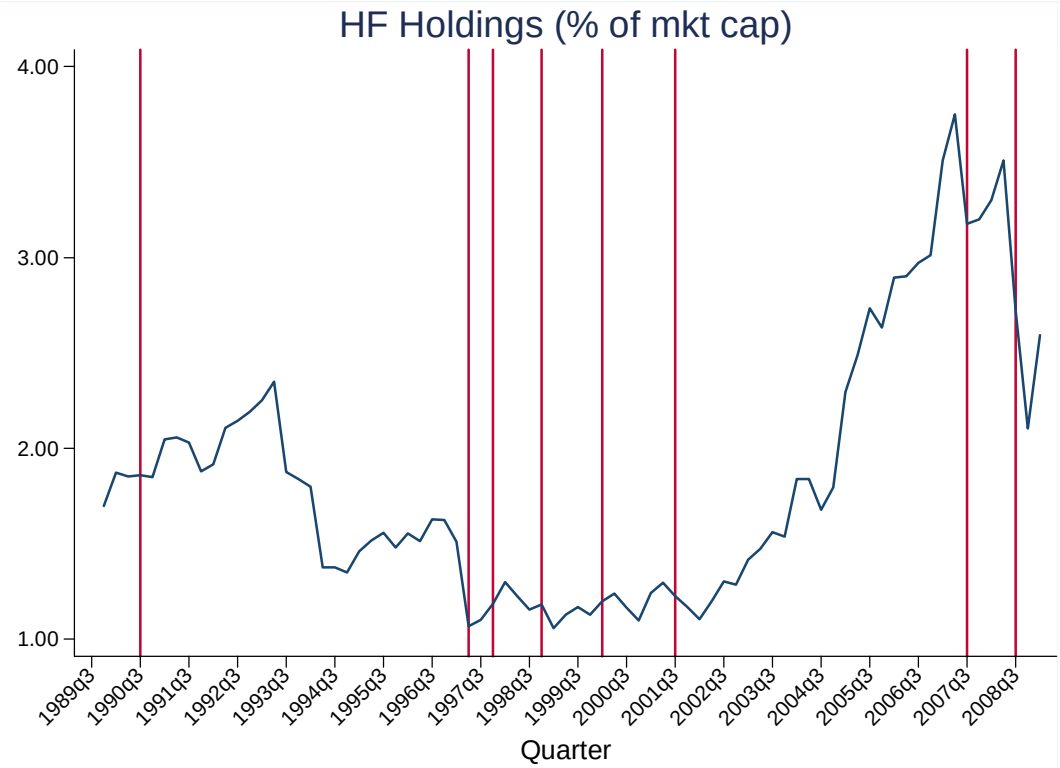

Figure 2. Time Series Aggregate Short Interest (% of Total Market Capitalization)

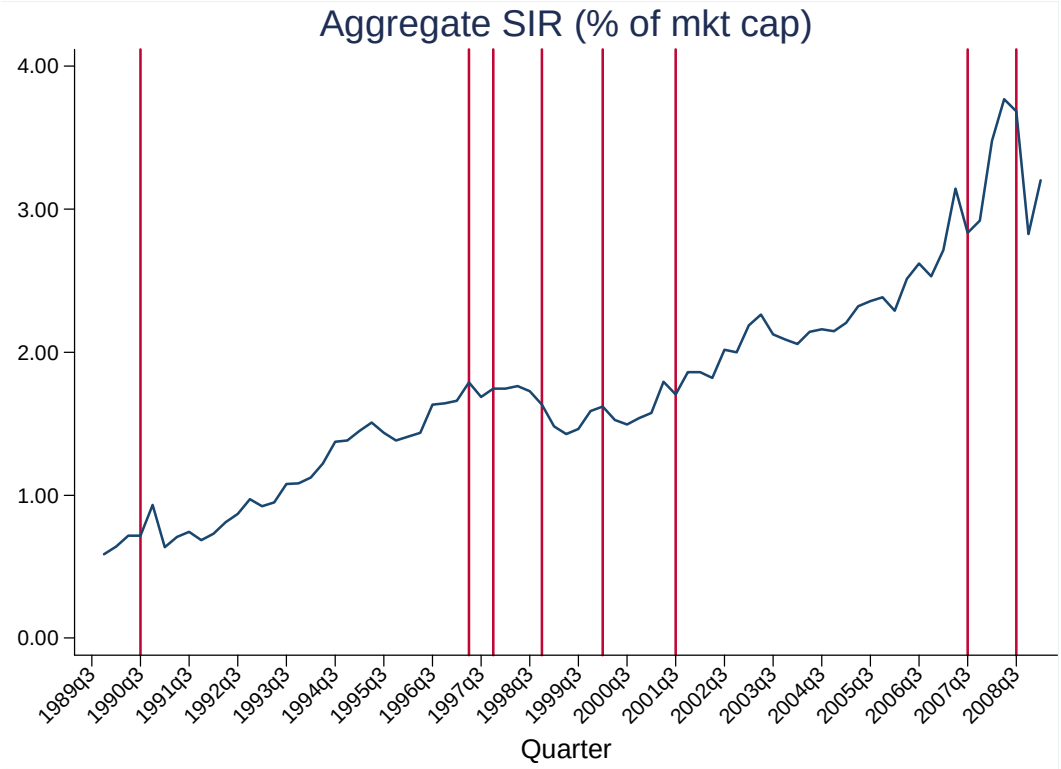

Figure 3a. Distribution of Hedge Fund Trades, Unconditionally and during Crises

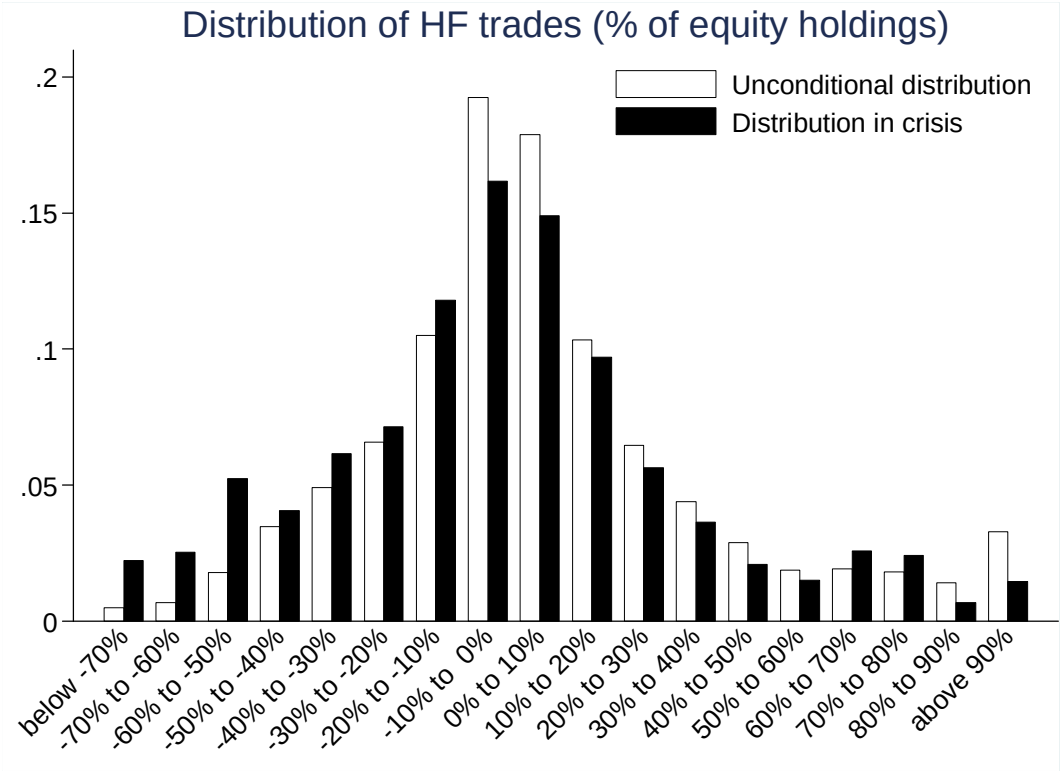

Figure 3b. Distribution of Hedge Fund Trades, Unconditionally and during the 2008 Crisis

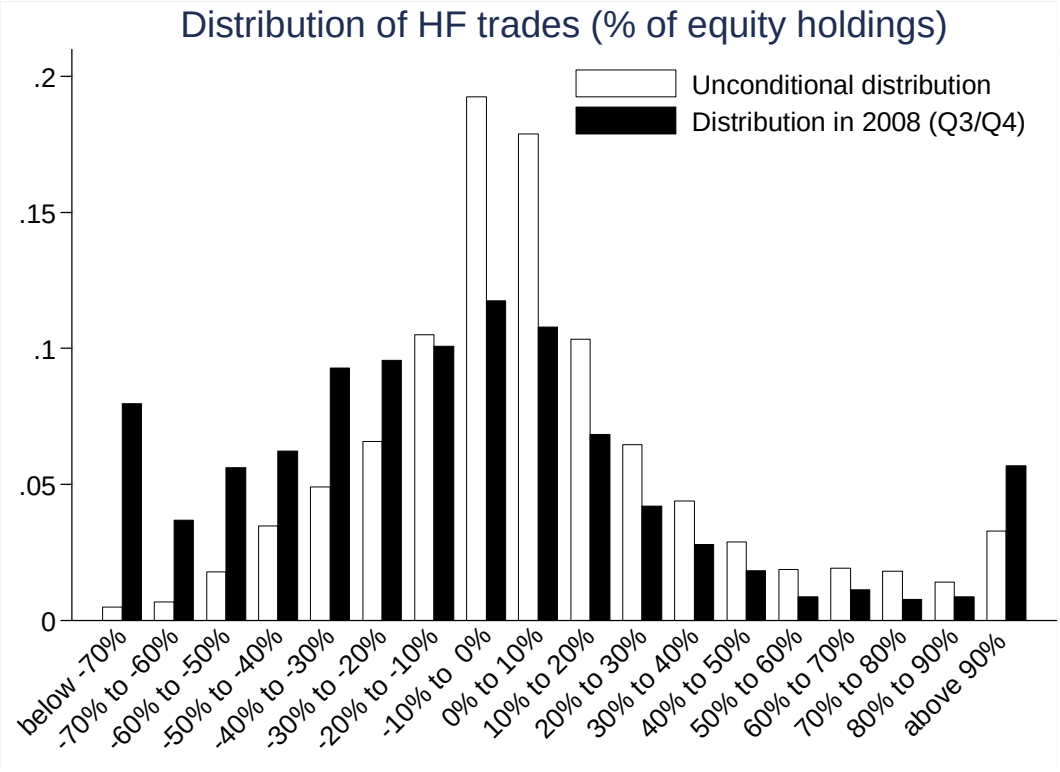

Table 1. Summary Statistics

The table presents summary statistics for the data used in the study. The sample period is the Q3/1989 to Q1/2009: the first quarter is used to calculate the differenced variables. Panel A presents summary statistics for the hedge fund holdings sample, aggregated at the calendar quarter level. Panel B similarly presents summary statistics for the hedge fund holdings sample, aggregated at the stock-calendar quarter level. Panel C provides the same statistics, aggregated at the hedge-fund-calendar quarter level. Panel D presents time-series summary statistics for hedge funds, aggregated at the hedge-fund-year level. Panel E shows correlations between the market-condition variables used in the study. Panel F lists the crises for the market condition variables. A crisis quarter is defined as a quarter in which the market condition variable is two standard deviations or more from the sample mean.

Panel A: Summary Statistics for Aggregate Sample (Quarterly Frequency)

	N	Mean	St.Dev.	Min	Median	Max
HF holdings over mkt cap (%)	78	1.840	0.686	1.060	1.650	3.750
Δ HF Holdings (%, share of equity holdings)	78	1.610	6.880	-16.600	0.652	37.000
Δ HF Holdings (%, share of mkt cap)	78	0.027	0.145	-0.583	0.011	0.499
MF holdings over mkt cap (%)	78	11.900	3.500	4.920	13.000	17.000
Δ MF Holdings (%, share of mkt cap)	78	0.105	0.232	-0.852	0.108	0.725
Other inst. holdings over mkt cap (%)	78	40.000	4.410	31.900	38.300	49.800
Δ Other inst. holdings (%, share of mkt cap)	78	0.157	0.900	-2.740	0.233	2.730
Retail holdings over mkt cap (%)	78	46.200	7.660	30.800	48.800	59.900
Δ Retail holdings (%, share of mkt cap)	78	-0.289	1.030	-3.410	-0.318	3.290
Short interest ratio (SIR) (%)	78	1.750	0.738	0.589	1.650	3.770
Δ Short interest ratio (Δ SIR) (%)	78	0.035	0.167	-0.683	0.035	0.653
Pastor-Stambaugh (PS)	77	0.006	0.109	-0.294	0.030	0.303
Minus Acharya-Pedersen (AP)	73	-0.521	1.740	-5.350	-0.532	3.390
Minus ΔVIX (VIX)	78	-0.364	6.260	-22.100	-0.060	16.500
R_m- R_f	78	0.010	0.084	-0.240	0.016	0.203

Panel B: Summary Statistics for Stock-Level Sample (Quarterly Frequency)

	N	Mean	St.Dev.	Min	Median	Max
Hedge fund equity holdings (%)	449256	3.096	5.883	0.000	0.780	100.000
Δ Hedge fund equity holdings (%)	431438	0.070	1.214	-5.419	0.000	6.570
Short interest ratio (SIR) (%)	573099	1.990	4.663	0.000	0.341	100.000
Δ Short interest ratio (SIR) (%)	543633	0.043	2.455	-92.309	0.000	89.516
Mktcap ($bn)	470817	1602.761	10083.571	0.011	111.994	602432.938
Volatility	421236	0.151	0.095	0.000	0.126	0.500
Past ret 12	453907	0.147	0.862	-0.999	0.03	58.68

Table 1. Summary Statistics (Cont.)

Panel C: Summary Statistics for Hedge-Fund-Level Sample (Quarterly Frequency)

	N	Mean	St.Dev.	Min	Median	Max
Δ HF Holdings (%, share of equity holdings)	18091	4.59	27.1	-66.1	1.21	122
Fund flows (%, share of equity holdings)	4586	-3.36	130	-2810	0.304	302
Fund return next quarter (%, ret(Q+1))	4949	2.24	8.88	-56.2	2.15	77.5
Fund return in two quarters (%, ret(Q+2))	4688	2.2	8.97	-56.2	2.17	77.5
Equity holdings return next quarter (%, eqret(Q+1))	16759	0.881	14.4	-81.4	1.92	246
Equity holdings return in two quarters (%, eqret(Q+2))	15815	0.798	14.5	-81.4	1.93	246
Return past 12 months (%, Past ret 12)	4547	11.2	21.8	-84.9	9.77	225
Equity portfolio size (log(assets))	18091	19.2	1.59	9.73	19.2	24.7
Put dummy	12278	0.32	0.467	0	0	1
Avg leverage	2181	1.09	0.898	0.00	1	8.35
Convertible arbitrage	5328	0.0535	0.216	0	0	1
Short bias	5328	0.00163	0.0286	0	0	0.729
Emerging markets	5328	0.0202	0.127	0	0	1
Market neutral	5328	0.0425	0.19	0	0	1
Event driven	5328	0.198	0.388	0	0	1
Fixed income arbtrage	5328	0.0144	0.112	0	0	1
Fund of funds	5328	0.0283	0.15	0	0	1
Global macro	5328	0.0402	0.188	0	0	1
Long-short	5328	0.52	0.488	0	0.837	1
Futures	5328	0.0167	0.119	0	0	1
Multistrategy	5328	0.0646	0.221	0	0	1

Table 1. Summary Statistics (Cont.)

Panel D: Summary Statistics for Hedge-Fund-Level, by Year

Year	Total Assets Under Mngmt in TASS ($bn)	Number of Mgrs.		Avg. Equity portfolio ($m)			Number of Stocks per manager			Portfolio turnover		
		13F	TASS match	Mean	Median	St. dev.	Mean	Median	St. dev.	Mean	Median	St. dev.
1989	2.2	38	3	1,264	278	3,406	179.0	87.5	271	0.62	0.48	0.56
1990	1.6	46	5	1,076	245	2,904	184.0	79.0	277	0.70	0.52	0.64
1991	2.6	50	8	1,315	238	3,518	194.0	82.0	295	0.71	0.58	0.57
1992	4.6	59	10	1,326	207	3,588	184.0	79.0	289	0.71	0.55	0.61
1993	8.8	68	16	1,323	219	3,581	184.0	76.0	363	0.80	0.63	0.66
1994	14.3	75	22	869	180	2,114	133.0	74.0	247	0.80	0.62	0.68
1995	17.3	88	23	961	252	2,090	135.0	72.0	177	0.87	0.74	0.67
1996	22.8	101	27	1,101	270	2,848	137.0	58.0	204	0.88	0.75	0.65
1997	30.7	113	31	971	283	2,381	125.0	55.0	204	0.96	0.78	0.74
1998	40.0	158	52	902	263	2,222	119.0	53.0	218	0.91	0.75	0.74
1999	29.0	171	59	925	250	2,547	104.0	49.0	196	1.05	0.90	0.79
2000	39.0	220	72	848	261	2,638	92.3	46.0	179	1.15	1.02	0.84
2001	41.5	258	83	599	163	1,812	91.9	41.0	190	1.15	1.02	0.89
2002	52.2	272	87	496	137	1,530	85.5	41.0	165	1.19	1.07	0.87
2003	65.3	295	97	572	176	1,672	94.5	43.0	186	1.23	1.12	0.86
2004	93.1	366	109	653	240	1,599	91.9	42.0	193	1.22	1.10	0.81
2005	112.2	441	132	819	271	2,013	96.5	40.0	216	1.16	1.04	0.77
2006	147.4	520	140	891	250	2,386	98.3	35.0	238	1.12	1.03	0.75
2007	189.4	595	145	977	269	2,804	93.1	34.0	229	1.15	1.03	0.79
2008	149.2	629	119	648	146	2,010	72.1	25.0	204	1.06	0.93	0.81
2009	77.1	545	76	418	87	1,300	67.0	21.0	197	1.16	0.96	0.99

Panel E: Correlations of Market Condition Variables

	Factor correlations			
	PS	AP	VIX	$R_m - R_f$
Pastor-Stambaugh (PS)	1.00			
Minus Acharya-Pedersen (AP)	0.23	1.00		
Minus ΔVIX (VIX)	0.35	0.15	1.00	
$R_m - R_f$	0.35	0.24	0.71	1.00

Panel F: Crisis Quarters (Quarters in which Market Condition Factor < -2σ)

Market Condition Factor			
PS	AP	VIX	R_m-R_f
1998q3	1998q3	1998q3	1990q3
2000q2	2007q3	2001q3	2001q3
2007q3		2002q3	2002q3
2008q1		2008q3	2008q4
2008q3			

Table 2. Hedge Fund Trades and Aggregate Liquidity

The table presents time-series OLS regressions. The explanatory variable is the change in aggregate hedge fund dollar holdings between two quarters. To be included in the sample, a hedge fund must have equity holdings in both quarters. Panel A and C regress the changes in aggregate hedge fund holdings on market condition variables dummies. Panels B and D regress the changes in aggregate hedge fund holdings on contemporaneous, lagged, and lead market condition variables. Panels A and B express the changes in hedge fund holdings as a percentage of total hedge fund holdings. Panels C and D express the changes in hedge fund holdings as a percentage of total equity market cap, using lagged quarter valuations. In Columns (1) and (2), the market condition variable is the Pastor-Stambaugh liquidity index. In Columns (3), (4), and (5), the market condition variables are the Acharya-Pedersen liquidity index, the VIX index, and the market's excess returns, respectively. All regressions have a constant which is not presented. *t*-statistics are presented in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

Panel A: Changes in Aggregate Hedge Fund Holdings and Non-Parametric Liquidity Measures

	Dependent variable: Δ HF total holdings (%)				
	PS	AP	VIX	$R_m - R_f$	PS
	(1)	(2)	(3)	(4)	(5)
Factor ≥ 2σ	3.889	-4.512	3.598	-5.910	4.167
	(0.579)	(-0.713)	(0.802)	(-1.179)	(0.659)
σ ≤ Factor < 2σ	-0.689	2.303	-5.054	-1.177	-0.442
	(-0.273)	(1.060)	(-1.187)	(-0.422)	(-0.186)
-σ ≤ Factor < σ					
-2σ ≤ Factor < -σ	-2.159	-1.166	-0.002	-0.016	0.467
	(-0.677)	(-0.439)	(-0.000)	(-0.006)	(0.150)
Factor < -2σ	-9.863***	-10.768**	-5.293	-2.637	-6.881*
	(-2.802)	(-2.277)	(-1.144)	(-0.731)	(-1.994)
dummy(Q3/Q4-2008)					-16.443***
					(-3.116)
Constant	-0.094	4.150	2.013	2.003**	3.360
	(-0.028)	(1.115)	(0.446)	(2.170)	(0.987)
FE for market returns	Yes	Yes	Yes	No	Yes
Observations	77	73	78	78	77
Adj R^2	0.035	0.024	-0.034	-0.027	0.145

Table 2. Hedge Fund Trades and Aggregate Liquidity (Cont.)

Panel B: Changes in Aggregate Hedge Fund Holdings and Lead/Lags Of Liquidity Measures

	Dependent variable: Δ HF total holdings (%)			
	PS	AP	VIX	$R_m - R_f$
	(1)	(2)	(3)	(4)
lag(Factor < -2σ)	-2.915	1.297	-6.243	0.771
	(-0.758)	(0.191)	(-1.610)	(0.215)
Factor < -2σ	-9.159***	-10.980**	-5.859	-2.472
	(-2.910)	(-2.368)	(-1.541)	(-0.689)
lead(Factor < -2σ)	1.610	3.727	5.482	-2.767
	(0.470)	(0.805)	(1.424)	(-0.772)
lag(Mkt ret)	-7.495	-3.981	-12.021	
	(-0.742)	(-0.403)	(-1.172)	
Mkt ret	-11.594	-12.028	-1.514	
	(-1.177)	(-1.184)	(-0.152)	
lead(Mkt ret)	9.520	7.097	23.996**	
	(1.021)	(0.721)	(2.458)	
Constant	2.482***	2.241***	1.812**	1.838**
	(2.858)	(2.662)	(2.000)	(2.144)
Observations	76	72	78	78
Adj R^2	0.065	0.015	0.079	-0.025

Table 2. Hedge Fund Trades and Aggregate Liquidity (Cont.)

Panel C: Changes in Aggregate Hedge Fund Holdings (Measured as % of Total Market Capitalization) and Non-Parametric Liquidity Measures

	Dependent variable: Δ HF holdings (% of total mktcap)				
	PS	AP	VIX	$R_m - R_f$	PS
	(1)	(2)	(3)	(4)	(5)
Factor ≥ 2σ	0.026	-0.068	0.030	-0.088	0.034
	(0.191)	(-0.604)	(0.317)	(-0.832)	(0.289)
σ ≤ Factor < 2σ	0.013	0.044	-0.084	-0.025	0.021
	(0.262)	(1.131)	(-0.939)	(-0.422)	(0.464)
-σ ≤ Factor < σ					
-2σ ≤ Factor < -σ	-0.075	-0.024	-0.013	-0.037	0.002
	(-1.150)	(-0.511)	(-0.139)	(-0.673)	(0.035)
Factor < -2σ	-0.247***	-0.279***	-0.166*	-0.101	-0.160**
	(-3.447)	(-3.298)	(-1.709)	(-1.325)	(-2.475)
dummy(Q3/Q4-2008)					-0.480***
					(-4.859)
Constant	-0.042	0.053	0.026	0.040**	0.059
	(-0.599)	(0.793)	(0.275)	(2.076)	(0.929)
FE for market returns	Yes	Yes	Yes	No	Yes
Observations	77	73	78	78	77
Adj R^2	0.108	0.088	-0.017	-0.018	0.331

Table 2. Hedge Fund Trades and Aggregate Liquidity (Cont.)

Panel D: Changes in Aggregate Hedge Fund Holdings (Measured as % of Total Market Capitalization) and Lead/Lags of Liquidity Measures

	Dependent variable: Δ HF holdings (% of total mktcap)				
	PS	AP	VIX	$R_m - R_f$	PS
	(1)	(2)	(3)	(4)	(5)
lag(Factor < -2σ)	-0.068	-0.001	-0.147*	0.022	-0.077
	(-0.901)	(-0.008)	(-1.895)	(0.301)	(-1.135)
Factor < -2σ	-0.223***	-0.283***	-0.184**	-0.099	-0.222***
	(-3.612)	(-3.542)	(-2.419)	(-1.344)	(-3.288)
lead(Factor < -2σ)	0.098	0.169**	0.123	-0.151**	0.079
	(1.461)	(2.120)	(1.597)	(-2.051)	(1.304)
dummy(Q3/Q4-2008)					-0.617***
					(-4.990)
lag(Mkt ret)	-0.158	-0.061	-0.250		-0.137
	(-0.797)	(-0.360)	(-1.217)		(-0.773)
Mkt ret	-0.123	-0.149	0.060		-0.170
	(-0.637)	(-0.852)	(0.302)		(-0.997)
lead(Mkt ret)	0.351*	0.217	0.639***		0.151
	(1.922)	(1.279)	(3.272)		(0.859)
Constant	0.041**	0.039***	0.032*	0.039**	0.047***
	(2.397)	(2.674)	(1.775)	(2.195)	(3.150)
Observations	76	72	78	78	76
Adj R^2	0.166	0.139	0.180	0.037	0.334

Table 3. Short Selling Activity around Liquidity Crises

The table presents time-series OLS regressions. The explanatory variable is the change in value-weighted aggregate short interest between two quarters. In Panels A and B, the dependent variable is the change in weighted aggregate short interest over the calendar quarter, in percentage points. In Panel C, the dependent variable is the stock-quarter level change in hedge fund holdings, in percentage points. In Columns (1) and (2), the market condition factor is the Pastor-Stambaugh liquidity index. In Columns (3), (4), and (5), the market condition variables are the Acharya-Pedersen liquidity index, the VIX index, and the market's excess returns, respectively. All regressions have a constant which is not presented. *t*-statistics are presented in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. In Panel C, robust standard errors are clustered at the calendar quarter level.

Panel A: Aggregate Short Interest and Liquidity Factors, Non-Parametric

	Dependent variable: Δ Agg Short Interest Ratio (%)				
	PS	AP	VIX	$R_m - R_f$	PS
	(1)	(2)	(3)	(4)	(5)
Factor ≥ 2σ	0.135	-0.236**	0.001	-0.114	0.143
	(0.860)	(-2.156)	(0.010)	(-0.986)	(1.017)
σ ≤ Factor < 2σ	0.090	-0.104***	-0.004	-0.083	0.097*
	(1.440)	(-2.770)	(-0.036)	(-1.295)	(1.731)
-σ ≤ Factor < σ					
-2σ ≤ Factor < -σ	-0.157**	0.028	0.094	0.129**	-0.079
	(-2.091)	(0.619)	(0.933)	(2.003)	(-1.135)
Factor < -2σ	-0.083	-0.209**	0.004	-0.129	0.003
	(-0.977)	(-2.531)	(0.039)	(-1.552)	(0.044)
dummy(Q3/Q4-2008)					-0.498***
					(-4.235)
FE for market returns	Yes	Yes	Yes	No	Yes
Observations	77	73	78	78	77
Adj R^2	0.096	0.191	0.029	0.071	0.276

Table 3. Short Selling Activity around Liquidity Crises

Panel B: Changes in Aggregate Short Interest and Liquidity Factors

	Dependent variable: Δ Agg Short Interest Ratio (%)			
	PS	AP	VIX	$R_m - R_f$
	(1)	(2)	(3)	(4)
lag(Factor < -2σ)	-0.114	-0.195**	-0.008	0.183*
	(-1.467)	(-2.036)	(-0.067)	(1.970)
Factor < -2σ	-0.027	-0.191***	-0.104	-0.150
	(-0.427)	(-2.924)	(-0.844)	(-1.615)
lead(Factor < -2σ)	0.269***	0.307***	0.030	-0.047
	(3.875)	(4.716)	(0.248)	(-0.507)
lag(Mkt ret)	-0.893***	-0.696***	-0.714**	
	(-4.361)	(-5.007)	(-2.349)	
Mkt ret	-0.525**	-0.395***	-0.050	
	(-2.632)	(-2.764)	(-0.173)	
lead(Mkt ret)	0.334*	0.310**	0.375	
	(1.769)	(2.241)	(1.366)	
Observations	76	72	78	78
Adj R^2	0.283	0.430	0.065	0.051

Panel C: Changes in Aggregate Short Interest and Liquidity Factors

	Dependent variable: Δ HF holdings (%)				
	PS	AP	VIX	$R_m - R_f$	Q3-Q4/2008
	(1)	(2)	(3)	(4)	(5)
Factor < -2σ	-0.320***	-0.396***	-0.053**	-0.293**	
	(-2.856)	(-6.678)	(-1.994)	(-1.995)	
Factor < -2σ × Δ Short Interest Ratio	0.011	0.025	-0.036***	0.070***	
	(0.542)	(1.373)	(-3.470)	(2.935)	
Δ Short Interest Ratio	0.103***	0.093***	0.106***	0.098***	0.111***
	(8.625)	(11.552)	(10.111)	(12.980)	(13.455)
Constant	0.123***	0.141***	0.098***	0.114***	-0.695***
	(4.839)	(6.708)	(3.666)	(4.651)	(-25.443)
Observations	305341	289177	309265	309265	7934
Adj R^2	0.011	0.008	0.009	0.011	0.022

Table 4. The Distribution of Hedge Fund Trades

The table presents results about the distribution of hedge fund trades. Panel A presents the distribution of hedge fund trades with respect to innovations in the Pastor and Stambaugh liquidity index. Panel B repeats the analysis in Panel A, but weighs the buckets by hedge fund dollar holdings.

Panel A: Equally Weighted Distribution of Hedge Fund Trades

	Equally-Weighted							
% HFs that trade:	Unconditional	$PS < -2\sigma$	$-2\sigma \leq PS < -\sigma$	$-\sigma \leq PS < 0$	$0 \leq PS < \sigma$	$\sigma \leq PS < 2\sigma$	$PS \geq 2\sigma$	Q3-Q4/2008
Buy 20%+	24.01	20.59	25.70	25.10	23.53	25.10	27.84	18.32
Buy 10%-20%	10.48	10.21	8.97	9.84	10.98	11.52	9.02	6.84
Buy 5%-10%	7.83	6.70	5.53	8.01	8.68	7.70	6.67	4.65
Unchanged ±5%	21.76	18.31	17.18	22.38	23.24	22.20	25.49	13.58
Sell 5%-10%	7.92	6.33	5.73	8.37	8.58	8.18	7.45	4.38
Sell 10%-20%	10.33	11.66	9.48	10.06	10.56	9.67	8.63	9.99
Sell 20%-40%	10.38	12.62	15.27	9.87	9.12	9.79	9.02	18.84
Sell 40%+	7.30	13.58	12.15	6.38	5.32	5.84	5.88	23.40
N	17,546	2,195	1,572	4,156	6,886	2,482	255	1,141

Panel B: Value-Weighted Distribution of Hedge Fund Trades

	Value-Weighted							
% HFs that trade:	Unconditional	$PS < -2\sigma$	$-2\sigma \leq PS < -\sigma$	$-\sigma \leq PS < 0$	$0 \leq PS < \sigma$	$\sigma \leq PS < 2\sigma$	$PS \geq 2\sigma$	Q3-Q4/2008
Buy 20%+	13.78	10.61	17.08	14.20	12.99	16.90	11.94	9.30
Buy 10%-20%	11.03	9.85	7.45	9.08	12.19	14.31	6.21	6.16
Buy 5%-10%	10.52	10.26	3.97	9.27	12.55	9.92	17.65	5.85
Unchanged ±5%	31.50	20.88	27.31	36.41	33.43	29.38	46.68	19.14
Sell 5%-10%	9.67	12.49	7.82	8.86	10.29	7.63	6.86	6.77
Sell 10%-20%	10.90	11.10	11.79	11.19	10.60	11.14	3.98	13.45
Sell 20%-40%	8.07	12.72	14.12	7.94	5.38	8.37	4.58	15.93
Sell 40%+	4.54	12.08	10.45	3.06	2.57	2.35	2.11	23.39
N	17,546	2,195	1,572	4,156	6,886	2,482	255	1,141

Table 5. Who Buys the Stocks that Hedge Funds Sell?

The table presents results about trades during crises by investor type. The table regresses changes in aggregate holdings by investor type on crisis indicators. Crisis is measured based on the Pastor and Stambaugh index. In Columns (1) and (2), the dependent variable is the change in aggregate holdings by mutual funds. In Columns (3) and (4), the dependent variable is the change in aggregate holdings by institutions which are not hedge funds or mutual funds. In Columns (5) and (6), the dependent variable is the change in aggregate holdings by retail investors. All regressions include a constant, which is not presented. *t*-statistics are presented in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively.

	Dependent variable: Δ total holdings (%) of …					
	Mutual funds		Other institutions		Retail investors	
	(1)	(2)	(3)	(4)	(5)	(6)
$PS \geq 2\sigma$	0.088	0.089	0.527	0.532	-0.586	-0.608
	(0.380)	(0.378)	(0.597)	(0.599)	(-0.338)	(-0.351)
$\sigma \leq PS < 2\sigma$	0.059	0.059	0.207	0.212	-0.688	-0.708
	(0.670)	(0.668)	(0.625)	(0.635)	(-1.058)	(-1.087)
$-\sigma \leq PS < \sigma$						
$-2\sigma \leq PS < -\sigma$	-0.237**	-0.235**	-0.320	-0.271	0.472	0.256
	(-2.145)	(-2.027)	(-0.764)	(-0.619)	(0.574)	(0.300)
$PS < -2\sigma$	0.023	0.026	0.745	0.801	-0.875	-1.120
	(0.185)	(0.200)	(1.613)	(1.655)	(-0.964)	(-1.185)
dummy(Q3/Q4-2008)		-0.017		-0.307		1.353
		(-0.087)		(-0.415)		(0.935)
FE for market returns	Yes	Yes	Yes	Yes	Yes	Yes
Observations	77	77	77	77	77	77
Adj R^2	0.022	0.008	-0.003	-0.015	-0.045	-0.047

Table 6. What Explains Hedge Funds' Equity Market Participation during Crises?

The table presents results about the relation between hedge fund trades and net fund flows, hedge fund leverage, flows into other assets, and investment in put options. In Panel A, the market condition variable is the Pastor-Stambaugh liquidity index. The sample used in Column (10) is restricted to observations in the last two quarters of 2008. In Panel B, the market condition variable is the Acharya-Pedersen liquidity index. In Panel C, the market condition variable is the VIX index. In Panel D, the market condition variable is the market's excess returns. All regressions include a constant, which is not presented. *t*-statistics are presented in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors are clustered by calendar quarter, except for Column (10), which does not have clustering.

Panel A: Explaining Changes in Hedge Fund Equity Holdings (Crisis Defined by Pastor and Stambaugh)

	Dependent variable: Δ HF equity portfolio (%)										
	Full sample										Q3-Q4/2008
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
PS < -2σ	-6.212***	-4.950***	-8.769***	-5.188	-3.857	-7.449***	-5.419*	-8.753**	-2.793	-0.693	
	(-3.076)	(-3.247)	(-3.207)	(-1.666)	(-1.663)	(-2.810)	(-1.972)	(-2.261)	(-0.778)	(-0.205)	
PS < -2σ × Fund flows		-0.019			-0.020				-0.031	-0.034	
		(-0.937)			(-0.820)				(-1.339)	(-1.464)	
PS < -2σ × lead(Fund flows)		-0.034*			-0.042*				-0.043	-0.042	
		(-1.790)			(-1.920)				(-1.591)	(-1.558)	
PS < -2σ × lead2(Fund flows)		-0.003			-0.002				-0.001	-0.001	
		(-0.716)			(-0.429)				(-0.097)	(-0.107)	
Fund flows		0.025			0.010				0.021	0.022	-0.032***
		(1.303)			(0.457)				(1.052)	(1.098)	(-4.943)
lead(Fund flows)		0.060***			0.064***				0.065**	0.064**	0.005**
		(3.115)			(2.915)				(2.401)	(2.378)	(2.343)
lead2(Fund flows)		0.002			0.003				0.002	0.002	
		(0.511)			(0.682)				(0.226)	(0.233)	
PS < -2σ × Avg leverage				-4.720***	-3.636**				-3.670*	-3.177	
				(-3.052)	(-2.134)				(-1.716)	(-1.547)	
Avg. leverage				1.825*	1.560				0.615	0.386	-2.048
				(1.732)	(1.532)				(0.550)	(0.315)	(-0.587)
PS < -2σ × Put dummy							-5.460***			-6.993**	
							(-3.830)			(-2.221)	
Put dummy							2.906**			2.855	-12.506
							(2.164)			(1.523)	(-1.595)
Past ret 12	11.468***	7.912***	11.488***	11.734***	8.692***	13.803***	13.882***	12.346**	7.951	8.395*	62.962***
	(4.285)	(2.961)	(3.886)	(3.932)	(2.904)	(2.974)	(3.023)	(2.398)	(1.603)	(1.705)	(2.832)
log(Portfolio size)	-6.213***	-6.015***	-6.320***	-6.221***	-6.178***	-6.596***	-6.650***	-6.107***	-5.939***	-6.053***	1.715
	(-8.220)	(-8.447)	(-7.083)	(-6.880)	(-7.366)	(-7.695)	(-7.669)	(-5.341)	(-5.748)	(-5.669)	(0.718)
Observations	3329	3329	2097	2097	2097	2771	2771	1512	1512	1512	92
Adj R^2	0.066	0.088	0.068	0.069	0.089	0.076	0.077	0.065	0.091	0.092	0.264

Table 6. What Explains Hedge Funds' Equity Market Participation during Crises? (Cont.)

Panel B: Explaining Changes in Hedge Fund Equity Holdings (Crisis Defined by Acharya and Pedersen)

	Dependent variable: Δ HF equity portfolio (%)									
	Full sample									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
AP < -2σ	-6.846***	-4.130***	-11.314***	-8.377***	-4.089	-7.674***	-5.346***	-12.045***	-2.246	-1.218
	(-5.763)	(-2.776)	(-9.853)	(-4.011)	(-1.628)	(-6.789)	(-5.269)	(-9.269)	(-1.355)	(-0.777)
AP < -2σ × Fund flows		-0.009			-0.040				-0.139***	-0.139***
		(-0.179)			(-0.674)				(-4.796)	(-4.811)
AP < -2σ × lead(Fund flows)		0.096***			0.067*				0.123***	0.124***
		(3.456)			(1.744)				(4.041)	(4.083)
AP < -2σ × lead2(Fund flows)		-0.025**			-0.034***				-0.041***	-0.040***
		(-2.100)			(-3.149)				(-3.441)	(-3.411)
Fund flows		0.018			-0.002				0.016	0.017
		(0.760)			(-0.055)				(0.570)	(0.583)
lead(Fund flows)		0.063***			0.063**				0.064*	0.062*
		(3.042)			(2.489)				(2.028)	(2.001)
lead2(Fund flows)		0.020			0.028***				0.035***	0.035***
		(1.645)			(2.696)				(2.890)	(2.888)
AP < -2σ × Avg leverage				-4.074**	-4.244***				-3.890***	-3.608**
				(-2.291)	(-3.426)				(-3.123)	(-2.599)
Avg. leverage				1.973*	1.734*				0.665	0.434
				(1.963)	(1.770)				(0.593)	(0.351)
AP < -2σ × Put dummy							-5.882***			-3.368*
							(-4.368)			(-1.861)
Put dummy							3.357**			2.772
							(2.391)			(1.427)
Past ret 12	10.269***	6.312**	10.299***	10.640***	7.712**	7.272*	7.430*	10.609*	6.339	6.759
	(3.831)	(2.341)	(3.310)	(3.386)	(2.425)	(1.909)	(1.958)	(1.940)	(1.177)	(1.265)
log(Portfolio size)	-6.537***	-6.147***	-6.847***	-6.720***	-6.451***	-6.879***	-6.964***	-6.694***	-6.185***	-6.324***
	(-8.317)	(-8.059)	(-7.616)	(-7.304)	(-7.330)	(-7.119)	(-7.107)	(-5.642)	(-5.490)	(-5.424)
Observations	3108	3108	1955	1955	1955	2414	2414	1380	1380	1380
Adj R^2	0.070	0.089	0.075	0.076	0.091	0.077	0.078	0.072	0.097	0.097

Table 6. What Explains Hedge Funds' Equity Market Participation during Crises? (Cont.)

Panel C: Explaining Changes in Hedge Fund Equity Holdings (Crisis Defined by VIX)

	Dependent variable: Δ HF equity portfolio (%)									
	Full sample									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
VIX < -2σ	-3.662	-1.842	-4.179	-3.384	-1.259	-5.574	-6.065	-2.538	3.407	2.344
	(-0.768)	(-0.432)	(-0.748)	(-0.698)	(-0.301)	(-0.776)	(-0.979)	(-0.263)	(0.431)	(0.359)
VIX < -2σ × Fund flows		-0.019			-0.011				0.000	0.006
		(-0.929)			(-0.527)				(0.018)	(0.246)
VIX < -2σ × lead(Fund flows)		-0.022			-0.030				-0.034	-0.035
		(-1.159)			(-1.404)				(-1.363)	(-1.391)
VIX < -2σ × lead2(Fund flows)		-0.003			-0.001				0.001	0.002
		(-0.714)			(-0.168)				(0.208)	(0.239)
Fund flows		0.026			0.010				0.016	0.016
		(1.432)			(0.487)				(0.842)	(0.860)
lead(Fund flows)		0.048**			0.051**				0.054**	0.054**
		(2.563)			(2.416)				(2.146)	(2.156)
lead2(Fund flows)		0.002			0.003				0.001	0.001
		(0.523)			(0.675)				(0.140)	(0.144)
VIX < -2σ × Avg leverage				-0.995	0.165				-2.166	-1.893
				(-0.482)	(0.099)				(-1.017)	(-0.867)
Avg. leverage				1.303	1.204				0.426	0.228
				(1.223)	(1.160)				(0.390)	(0.192)
VIX < -2σ × Put dummy							1.849			3.016
							(0.328)			(0.557)
Put dummy							2.011			2.245
							(1.612)			(1.250)
Past ret 12	11.519***	8.486***	11.760***	12.056***	9.654***	13.610***	13.670***	13.167**	9.563*	9.758*
	(4.197)	(3.021)	(3.632)	(3.661)	(2.897)	(3.180)	(3.226)	(2.507)	(1.835)	(1.895)
log(Portfolio size)	-6.268***	-6.110***	-6.427***	-6.346***	-6.326***	-6.745***	-6.799***	-6.161***	-6.065***	-6.187***
	(-8.219)	(-8.493)	(-7.190)	(-6.985)	(-7.483)	(-8.197)	(-8.172)	(-5.422)	(-5.902)	(-5.800)
Observations	3329	3329	2097	2097	2097	2835	2835	1512	1512	1512
Adj R^2	0.064	0.085	0.063	0.063	0.084	0.073	0.073	0.059	0.086	0.086

Table 6. What Explains Hedge Funds' Equity Market Participation during Crises? (Cont.)

Panel D: Explaining Changes in Hedge Fund Equity Holdings (Crisis Defined by R_m-R_f)

	Dependent variable: Δ HF equity portfolio (%)									
	Full sample									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
R_m-R_f < -2σ	2.524	3.863	4.002	3.677	3.981	-1.697	-1.682	9.616	5.412	-0.741
	(0.469)	(0.815)	(0.754)	(0.766)	(1.297)	(-0.277)	(-0.328)	(1.249)	(0.932)	(-0.106)
R_m-R_f < -2σ × Fund flows		-0.088***			-0.044*				0.379***	0.440***
		(-4.824)			(-1.856)				(11.973)	(19.140)
R_m-R_f < -2σ × lead(Fund flows)		0.080			0.044				-0.417***	-0.470***
		(1.630)			(0.511)				(-3.062)	(-5.029)
R_m-R_f < -2σ × lead2(Fund flows)		0.068***			0.055***				0.033***	0.022**
		(3.693)			(3.012)				(5.342)	(2.667)
Fund flows		0.031*			0.017				0.022	0.022
		(1.893)			(0.929)				(1.261)	(1.294)
lead(Fund flows)		0.030***			0.027***				0.027***	0.027***
		(4.777)			(3.980)				(3.744)	(3.741)
lead2(Fund flows)		-0.001			0.001				0.001	0.001
		(-0.913)			(1.143)				(0.653)	(0.686)
R_m-R_f < -2σ × Avg leverage				0.714	0.456				-1.636	-0.783
				(0.515)	(0.274)				(-0.595)	(-0.266)
Avg. leverage				1.246	1.207				0.436	0.249
				(1.205)	(1.200)				(0.409)	(0.217)
R_m-R_f < -2σ × Put dummy							0.684			17.350***
							(0.078)			(4.075)
Put dummy							2.111*			2.104
							(1.721)			(1.207)
Past ret 12	12.662***	9.501***	13.166***	13.453***	10.824***	14.335***	14.423***	14.621**	10.795**	10.897**
	(4.145)	(3.264)	(3.819)	(3.844)	(3.351)	(3.018)	(3.049)	(2.575)	(2.103)	(2.153)
log(Portfolio size)	-6.257***	-6.177***	-6.409***	-6.334***	-6.401***	-6.723***	-6.775***	-6.115***	-5.920***	-6.070***
	(-8.237)	(-8.401)	(-7.227)	(-7.016)	(-7.431)	(-8.019)	(-8.024)	(-5.416)	(-5.819)	(-5.769)
Observations	3329	3329	2097	2097	2097	2835	2835	1512	1512	1512
Adj R^2	0.064	0.084	0.063	0.063	0.082	0.072	0.072	0.061	0.090	0.092

Table 7. Hedge Fund Trades and Stock Volatility

The table tests whether hedge funds sell more high volatility stocks during crises. Panels A and B are at the stock-calendar quarter level. Panel A regresses changes in stock-level aggregate hedge fund holdings on crisis indicators interacted with a high volatility indicator (above median volatility, within the quarter). Panel B regresses changes in stock-level aggregate short interest on crisis indicators interacted with a high volatility indicator (above-median volatility, within the quarter). In Column (1), the market condition variable is the Pastor-Stambaugh liquidity index. In Column (2), it is the Acharya-Pedersen liquidity index, and the VIX index in Column (3). In Column (4), the market condition variable is the market's excess returns. In Column (5), the sample is restricted to the last two quarters of 2008. Panel C presents probit regressions (marginal effects are presented) of whether hedge funds dropped out of the sample of 13F and TASS, as a function of their trades during crises. *t*-statistics are presented in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors are clustered by calendar quarter.

Panel A: Changes in Hedge Fund Holdings and Stock Volatility

	Dependent variable: Δ HF holdings (%)				
	PS	AP	VIX	R_m - R_f	Q3-Q4/2008
	(1)	(2)	(3)	(4)	(5)
Factor < -2σ x High volatility	-0.192***	-0.161***	-0.006	-0.080	
	(-6.486)	(-4.556)	(-0.387)	(-1.229)	
Factor < -2σ	-0.187	-0.271**	-0.020	-0.246	
	(-1.490)	(-2.367)	(-0.932)	(-1.462)	
High volatility	0.040**	0.049***	0.023	0.027	-0.325***
	(2.083)	(2.881)	(1.148)	(1.440)	(-5.975)
log(Mktcap)	0.012	0.018***	0.010	0.010	-0.103***
	(1.594)	(2.745)	(1.250)	(1.313)	(-7.562)
Past ret 12	0.034***	0.019*	0.036**	0.032***	0.169***
	(2.746)	(1.993)	(2.640)	(2.732)	(2.680)
Constant	0.007	-0.008	0.006	0.017	-0.034
	(0.240)	(-0.303)	(0.210)	(0.540)	(-0.344)
Observations	385364	369469	389379	389379	7844
Adj. R^2	0.002	0.002	0.001	0.002	0.009

Table 7. Hedge Fund Trades and Stock Volatility (Cont.)

Panel B: Changes in Short Interest Ratio and Stock Volatility

	Dependent variable: Δ short interest ratio (SIR) (%)				
	PS	AP	VIX	$R_m - R_f$	Q3-Q4/2008
	(1)	(2)	(3)	(4)	(5)
Factor < -2σ x High volatility	-0.287***	-0.264	0.079***	-0.226	
	(-3.839)	(-1.661)	(3.632)	(-1.353)	
Factor < -2σ	0.086	-0.153**	-0.123***	-0.323	
	(0.453)	(-2.002)	(-4.297)	(-0.868)	
High volatility	-0.003	0.014	-0.027	-0.014	-0.839***
	(-0.106)	(0.719)	(-0.816)	(-0.523)	(-10.494)
log(Mktcap)	0.017	0.021**	0.017	0.018	-0.207***
	(1.299)	(2.622)	(1.303)	(1.445)	(-10.318)
Past ret 12	0.106***	0.089***	0.106***	0.100***	0.576***
	(4.805)	(6.210)	(4.685)	(5.663)	(6.528)
Constant	-0.058	-0.065*	-0.051	-0.040	0.552***
	(-1.124)	(-1.975)	(-1.022)	(-0.688)	(3.817)
Observations	368877	352068	373041	373041	8370
Adj. R^2	0.004	0.004	0.004	0.006	0.022

Table 8. Hedge Fund Behavior during Crises, by Hedge Fund Style

The table presents results about the relation between hedge fund trades and hedge fund style. In Columns (1) and (2), the market condition variable is the Pastor-Stambaugh liquidity index. In Columns (3) and (4), it is the Acharya-Pedersen liquidity index, and the VIX index in Columns (5) and (6). In Columns (7) and (8), the market condition variable is the market's excess returns. The sample used in Column (9) is restricted to observations in the last two quarters of 2008. All regressions include a constant, which is not presented. *t*-statistics are presented in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors are clustered by calendar quarter.

	Dependent variable: Δ HF equity portfolio (%)							
	PS		AP		VIX		$R_m - R_f$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Factor < -2σ × Convertible arb.	-8.583	-5.173	-2.849	2.431	2.182	4.584	23.002	30.416*
	(-0.852)	(-0.498)	(-0.278)	(0.211)	(0.126)	(0.234)	(1.211)	(1.910)
Factor < -2σ × Short bias	-66.901	-67.958	32.120	21.717	93.897**	89.394*	94.483**	93.002*
	(-1.435)	(-1.489)	(0.770)	(0.532)	(2.007)	(1.928)	(2.016)	(1.977)
Factor < -2σ × Emerging	-11.935*	-11.272*	-8.407	-9.260	83.392*	73.903	61.305	70.515*
	(-1.771)	(-1.709)	(-1.282)	(-1.049)	(1.799)	(1.606)	(1.171)	(1.704)
Factor < -2σ × Market neutral	20.510***	20.107***	28.910**	27.717**	35.779**	33.516**	148.944***	158.311***
	(3.798)	(3.800)	(2.056)	(2.066)	(2.278)	(2.518)	(20.274)	(23.887)
Factor < -2σ × Event driven	-10.467**	-9.271**	-15.492***	-15.762***	-8.115	-5.247	-0.725	-0.128
	(-2.591)	(-2.482)	(-6.650)	(-7.944)	(-1.503)	(-1.178)	(-0.231)	(-0.039)
Factor < -2σ × Fixed income arb.	-7.414	-5.577	-11.308	-8.105	10.568	12.282	15.623	15.297
	(-1.568)	(-1.113)	(-1.433)	(-1.315)	(0.519)	(0.609)	(0.591)	(0.607)
Factor < -2σ × Fund of funds	-9.288	-6.545	-13.468**	-8.138*	-16.952	-7.047	63.076	57.494
	(-0.939)	(-0.788)	(-2.535)	(-1.754)	(-1.389)	(-0.544)	(0.699)	(0.633)
Factor < -2σ × Global macro	-20.811	-20.704	-45.077***	-41.895***	-17.096**	-18.959***		
	(-1.574)	(-1.594)	(-13.293)	(-11.500)	(-2.435)	(-2.725)		
Factor < -2σ × Long-short	-1.279	-1.417	-1.739	-1.093	-4.360	-4.514	-3.646	-2.200
	(-0.643)	(-0.675)	(-0.830)	(-0.521)	(-1.443)	(-1.513)	(-0.851)	(-0.583)
Factor < -2σ × Futures	-47.160***	-35.661***	-52.041***	-36.728***	-78.037***	35.424*		
	(-3.603)	(-2.828)	(-9.082)	(-6.103)	(-8.431)	(1.869)		
Factor < -2σ × Multistrategy	-21.113**	-15.664*	-6.594**	-3.677	-1.548	7.583	17.095***	13.192***
	(-2.500)	(-1.968)	(-2.017)	(-0.952)	(-0.132)	(0.997)	(5.155)	(3.766)
Convertible arbitrage	2.790	2.410	2.255	2.762	2.796	2.890	3.852	3.017
	(0.442)	(0.401)	(0.344)	(0.450)	(0.471)	(0.509)	(0.651)	(0.546)
Short bias	9.418	16.967	1.815	11.091	-11.627	-3.876	-10.736	-4.869
	(0.209)	(0.382)	(0.043)	(0.269)	(-0.249)	(-0.084)	(-0.229)	(-0.105)
Emerging	-12.428	-11.024	-13.433	-11.794	-14.636**	-12.958*	-12.944*	-12.211*
	(-1.616)	(-1.468)	(-1.658)	(-1.533)	(-2.103)	(-1.925)	(-1.846)	(-1.841)
Market neutral	-4.595	-2.713	-6.824	-4.520	-3.189	-1.284	-0.329	0.556
	(-0.871)	(-0.536)	(-1.332)	(-0.942)	(-0.658)	(-0.273)	(-0.064)	(0.116)
Event driven	9.753*	10.865**	9.092*	10.475**	9.848**	11.077**	10.817**	11.329**
	(1.903)	(2.188)	(1.701)	(2.093)	(2.151)	(2.476)	(2.404)	(2.622)
Fixed income arbitrage	6.516	7.344	5.681	6.662	6.360	7.348	7.768	8.096
	(1.125)	(1.295)	(0.964)	(1.178)	(1.187)	(1.392)	(1.454)	(1.570)
Global macro	-2.538	-0.871	-3.738	-1.870	-3.338	-1.491	-2.396	-1.427
	(-0.494)	(-0.173)	(-0.697)	(-0.369)	(-0.719)	(-0.324)	(-0.527)	(-0.322)
Long-short	-6.699	-4.848	-7.624	-5.464	-5.872	-3.926	-4.626	-3.604
	(-1.373)	(-1.037)	(-1.512)	(-1.180)	(-1.347)	(-0.930)	(-1.071)	(-0.880)
Futures	-7.054	-3.817	-10.115	-7.632	-12.680	-8.701	-12.822*	-7.795
	(-0.890)	(-0.477)	(-1.321)	(-1.022)	(-1.601)	(-1.106)	(-1.679)	(-1.001)
Multistrategy	7.793	8.077	8.109	8.188	5.732	6.580	6.386	7.269
	(1.278)	(1.329)	(1.270)	(1.354)	(0.983)	(1.168)	(1.138)	(1.319)

Table continues on next page

Table 8. Hedge Fund Behavior during Crises, by Hedge Fund Style (Cont.)

Continued from previous page

Fund flows		0.020		0.011		0.020		0.024
		(1.030)		(0.473)		(1.091)		(1.453)
lead(Fund flows)		0.051**		0.056**		0.042**		0.029***
		(2.623)		(2.588)		(2.331)		(5.353)
lead2(Fund flows)		0.003		0.016		0.002		-0.000
		(0.836)		(1.098)		(0.703)		(-0.326)
Factor < -2σ × Fund flows		-0.020		0.005		-0.016		-0.032
		(-0.874)		(0.177)		(-0.723)		(-1.218)
Factor < -2σ × lead(Fund flows)		-0.030		0.039*		-0.012		0.072**
		(-1.546)		(1.819)		(-0.654)		(2.279)
Factor < -2σ × lead2(Fund flows)		-0.003		-0.009		-0.003		0.036*
		(-0.954)		(-0.646)		(-0.867)		(1.702)
Past ret 12	13.773***	10.492***	12.764***	9.233***	13.810***	10.833***	15.013***	12.084***
	(5.089)	(3.879)	(4.604)	(3.274)	(4.818)	(3.706)	(4.767)	(3.944)
log(Portfolio size)	-5.753***	-5.653***	-5.997***	-5.710***	-5.782***	-5.701***	-5.738***	-5.759***
	(-7.938)	(-8.175)	(-7.859)	(-7.582)	(-8.018)	(-8.264)	(-7.833)	(-8.063)
Observations	3322	3322	3101	3101	3322	3322	3322	3322
Adjusted R^2	0.105	0.119	0.111	0.122	0.100	0.115	0.099	0.116

Table 9. Hedge Fund Behavior during Crises and their Future Returns

The table explores the future total returns of hedge funds with respect to their equity trades during crises and their investment styles. Panel A explores the total returns of hedge funds in the following quarter. Panel B explores the total returns of hedge funds two quarters ahead. The sample is based on TASS and 13F, and consists of hedge-fund-quarters from the third quarter of 1989 through the second quarter of 2009. In Columns (1) and (5), the market condition variable is the Pastor-Stambaugh liquidity index. In Columns (2) and (6), it is the Acharya-Pedersen liquidity index, and the VIX index in Columns (3) and (7). In Columns (4) and (8), the market condition variable is the market's excess returns. All regressions include a constant, which is not presented. *t*-statistics are presented in parentheses. ***, **, and * represent statistical significance at the 1%, 5%, and 10% levels, respectively. Robust standard errors are clustered by calendar quarter.

	Total portfolio ret(Q+1) (%)				Total portfolio ret(Q+2) (%)			
	PS	AP	VIX	$R_m - R_f$	PS	AP	VIX	$R_m - R_f$
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Factor < -2σ	0.299	0.298	0.201	-0.507	-2.349**	-1.931	0.426	-0.293
	(0.455)	(0.314)	(0.266)	(-1.127)	(-2.210)	(-1.464)	(0.593)	(-0.536)
Factor < -2σ × max(Δ Equity portfolio,0)	0.021	-0.013	-0.024	-0.022	0.018	-0.007	0.013	0.024***
	(0.898)	(-0.285)	(-0.852)	(-1.088)	(0.564)	(-0.148)	(0.724)	(3.255)
Factor < -2σ × min(Δ Equity portfolio,0)	-0.009	-0.021	0.078	0.133**	-0.112***	-0.106***	-0.028	0.007
	(-0.199)	(-0.355)	(1.351)	(2.368)	(-4.467)	(-8.244)	(-0.882)	(0.289)
max(Δ Equity portfolio,0)	-0.006	-0.009*	-0.003	-0.003	0.006	0.005	0.007	0.007
	(-1.005)	(-1.791)	(-0.469)	(-0.590)	(0.975)	(0.958)	(1.183)	(1.153)
min(Δ Equity portfolio,0)	0.014	0.019	0.004	0.006	0.032**	0.025**	0.017	0.012
	(1.040)	(1.406)	(0.289)	(0.476)	(2.250)	(2.030)	(1.013)	(0.801)
Fund flows	-0.005	-0.008**	-0.005	-0.003	-0.005	-0.008***	-0.004	-0.003
	(-1.557)	(-2.359)	(-1.646)	(-1.487)	(-1.358)	(-2.831)	(-1.356)	(-1.380)
lead(Fund flows)	-0.005	-0.005	-0.005	-0.004***	0.001	0.004	0.000	-0.000
	(-1.059)	(-1.009)	(-1.449)	(-4.178)	(0.352)	(1.617)	(0.033)	(-0.373)
lead2(Fund flows)	0.003*	0.014***	0.004*	0.001***	-0.001**	-0.001	-0.001	-0.000**
	(1.729)	(4.557)	(1.683)	(4.235)	(-2.192)	(-0.538)	(-1.427)	(-2.361)
Factor < -2σ × Fund flows	0.008	0.014***	0.009	0.016	0.009	0.024***	0.012**	-0.023
	(1.644)	(4.027)	(1.481)	(0.707)	(1.247)	(4.418)	(2.271)	(-1.532)
Factor < -2σ × lead(Fund flows)	0.001	-0.024***	-0.000	0.002	-0.001	-0.029***	-0.001	0.027**
	(0.180)	(-3.601)	(-0.117)	(0.155)	(-0.313)	(-7.424)	(-0.234)	(2.369)
Factor < -2σ × lead2(Fund flows)	-0.002	0.014***	-0.003	-0.002	0.001*	0.019***	0.001	-0.010
	(-1.107)	(4.312)	(-1.239)	(-0.354)	(1.738)	(4.072)	(1.346)	(-1.353)
Past ret 12	0.045**	0.034*	0.042**	0.042**	0.007	0.002	0.012	0.008
	(2.249)	(1.718)	(2.056)	(2.150)	(0.437)	(0.113)	(0.698)	(0.505)
log(Portfolio size)	-0.126	-0.097	-0.119	-0.123	-0.060	-0.018	-0.062	-0.082
	(-1.248)	(-0.874)	(-1.156)	(-1.226)	(-0.608)	(-0.171)	(-0.610)	(-0.831)
ret(Equity portfolio, Q+1)	0.416***	0.417***	0.415***	0.422***				
	(15.629)	(16.037)	(16.275)	(16.811)				
ret(Equity portfolio, Q+2)					0.415***	0.414***	0.420***	0.417***
					(16.139)	(14.164)	(16.352)	(16.465)
Observations	3322	3101	3322	3322	3322	3101	3322	3322
Adjusted R^2	0.419	0.411	0.420	0.420	0.409	0.386	0.406	0.405