RFS Advance Access published November 17, 2011

Hedge Fund Stock Trading in the Financial Crisis of 2007–2009

Itzhak Ben-David
Fisher College of Business, Ohio State University

Francesco Franzoni
University of Lugano and Swiss Finance Institute

Rabih Moussawi
Wharton Research Data Services, Wharton School,
University of Pennsylvania

Hedge funds significantly reduced their equity holdings during the recent financial crisis. In 2008:Q3–Q4, hedge funds sold about 29% of their aggregate portfolio. Redemptions and margin calls were the primary drivers of selloffs. Consistent with forced deleveraging, the selloffs took place in volatile and liquid stocks. In comparison, redemptions and stock sales for mutual funds were not as severe. We show that hedge fund investors withdraw capital three times as intensely as mutual fund investors do in response to poor returns. We relate this stronger sensitivity to losses to share liquidity restrictions and institutional ownership in hedge funds. (*JEL* G01, G12, G14, G23)

Hedge funds are the investor class that most closely resembles textbook arbitrageurs: They engage in sophisticated trading strategies, use leverage, and take short positions. Despite these degrees of freedom, hedge funds depend on outside financing, which may curtail their ability to exploit profit opportunities (Shleifer and Vishny 1997; Gromb and Vayanos 2002; Vayanos 2004; Brunnermeier and Pedersen 2009; also see Gromb and Vayanos 2010 for a survey). Limits on hedge funds' arbitrage potential are likely to be more severe during market crises. At such times, in response to initial losses, capital providers, investors, and lenders may withdraw their funds and force the hedge funds to liquidate their positions prematurely. This behavior can deteriorate

We thank Viral Acharya, Giovanni Barone-Adesi, Jia Chen, Alexander Eisele, Vyacheslav Fos, Craig Furfine, YeeJin Jang, Robert Kowolski, Pete Kyle, José-Miguel Gaspar, Michael Halling, Massimo Massa, Stefan Nagel, Loriana Pelizzon, Alberto Plazzi, Steven Ongena, Tarun Ramadorai, Ronnie Sadka, René Stulz, Dimitri Vayanos, and seminar and conference participants at Brigham Young University, EFA (2011), Ohio State University, the University of Utah, the Office of the Comptroller of Currency, the 2nd Annual Conference on Hedge Funds in Paris, the 3rd Erasmus Liquidity Conference, the Wharton/FIRS pre-conference, the FDIC BRC Conference, the FIRS conference (Florence), LUISS University (Rome), the C.R.E.D.I.T. Conference (Venice), and AFA Meetings (Denver) for helpful comments. Send correspondence to Itzhak Ben-David, Fisher College of Business, Ohio State University; telephone: (614) 292-7843. E-mail: bendavid@fisher.osu.edu.

doi:10.1093/rfs/hhr114

liquidity in the market and cause further losses. Some empirical evidence reveals that during the recent financial crisis, the returns from providing liquidity increased (Nagel 2011) and the stocks traded by hedge funds that used Lehman Brothers as prime broker became less liquid (Aragon and Strahan 2011), which indirectly suggests that hedge funds withdrew from the market.[1]

In this article, we provide direct evidence on hedge fund trading in the U.S. stock market during the financial crisis of 2007–2009. We document the change in hedge funds' long stock positions, investigate the economic determinants of their trades, and analyze the difference in their behavior relative to mutual funds. Our study relies on a new dataset that originates from matching the institutional ownership of U.S. stocks from 13F filings to a proprietary list of hedge funds. These data are then manually matched to the Lipper TASS Hedge Fund Database and a dataset of Form ADV filings to compile information on hedge fund characteristics, performance, and ownership structure.

The main message of the article is that hedge funds exited the U.S. stock market en masse as the financial crisis evolved, primarily in response to the tightening of funding by investors and lenders.[2] Although hedge funds have provisions in place to limit redemptions, our results suggest that this was potentially a magnifying factor in causing hedge fund investors' withdrawals relative to mutual funds. Investors, fearing that the hedge fund would further constrain their ability to pull their money (e.g., by raising the gates), reacted promptly to the first signs of deteriorating performance. Our results support the theories of limits to arbitrage, which propose that arbitrageurs cannot operate in an unconstrained fashion due to their reliance on outside financing (e.g., Shleifer and Vishny 1997; Gromb and Vayanos 2002, 2010; Vayanos 2004; Brunnermeier and Pedersen 2009).

The stylized fact that we document and explore is the sharp decline in hedge funds' stock ownership during the recent financial crisis. Figure 1 plots the fraction of U.S. market capitalization held by the hedge funds in our dataset. The shaded areas denote the quarters around two events of special market stress: the Quant Meltdown (2007:Q3) and Lehman Brothers' bankruptcy (2008:Q3). The figure shows significant declines in hedge fund holdings around these events. More specifically, we find that hedge funds reduced their equity holdings by about 6% in each of the third and fourth quarters of 2007,

[1] Focusing on merger arbitrage following the 1987 crash and on convertible arbitrage in 2005, Mitchell, Pedersen, and Pulvino (2007) provide evidence that redemptions forced hedge funds to turn from liquidity providers into liquidity demanders. Mitchell and Pulvino (2011) focus on a set of relative value strategies during the recent crisis and argue that the disappearance of long-term financing caused arbitrageurs to withdraw liquidity from these markets, generating further price divergence.

[2] He, Khang, and Krishnamurthy (2010) report that the aggregate *value* of assets owned by hedge funds declined by $800bn. While their work portrays the balance sheets of institutions during the crisis, our study, in contrast, focuses on the *active selling* of U.S. stocks by hedge funds.

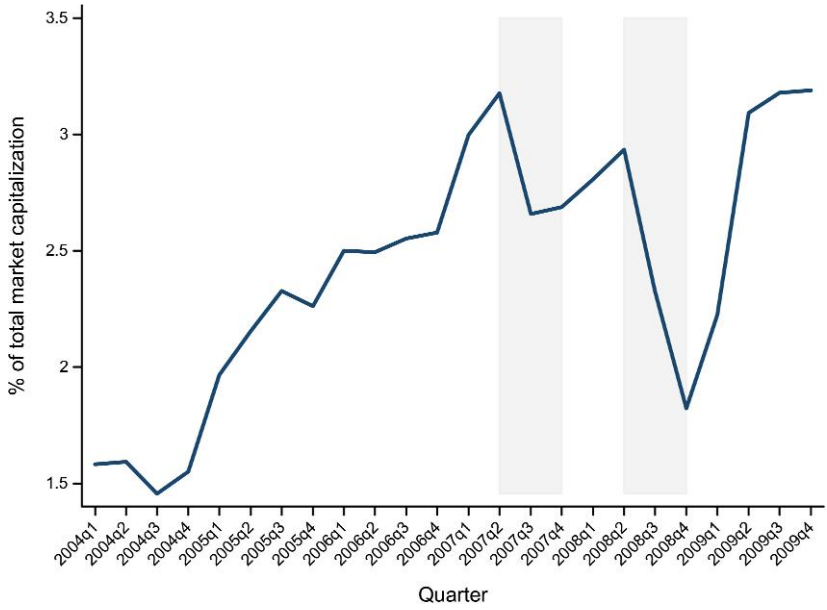

Figure 1
Time series of hedge funds' equity holdings (% of total market capitalization)
The figure plots the fraction of U.S. stock market capitalization held by the hedge funds in our sample. The shaded areas denote the quarters around the Quant Meltdown (2007:Q3) and Lehman Brothers' bankruptcy (2008:Q3). The series ranges from 2004Q1 to 2009Q4.

and by about 15% in each of the third and fourth quarters of 2008, on average.[3] We also document an aggregate decline in short interest[4] in these four quarters (for which the short-selling ban on financial stocks in September and October 2008 is also responsible). We show that the decline in long holdings and short interest did not cancel each other out, as there was only a small overlap between stocks that were sold by hedge funds and those that were bought to cover short positions. Rather, they both serve as evidence of the large deleveraging process that took place in the hedge fund sector. Complementary to our findings, Ang, Gorovyy, and van Inwegen (2010) show that hedge fund leverage decreased substantially during the crisis.

After establishing that hedge funds withdrew significantly from the stock market during the financial crisis, the goal of the article is to understand the economic forces behind the withdrawal. Guidance for our analysis comes from

[3] These figures translate to an exit of 0.2%, on average, of the total market capitalization in each of the third and fourth quarters of 2007, and to 0.4%, on average, of the total market capitalization in each of the third and fourth quarters of 2008.

[4] Because hedge fund short equity positions are not disclosed, we rely on the conjecture that most short selling is performed by hedge funds. Goldman Sachs (2010) estimates that as of March 2010, 85% of all equity short positions going through their brokerage house is performed by hedge funds.

theories suggesting that limits-to-arbitrage can emerge at times of market stress (e.g., Shleifer and Vishny 1997; Gromb and Vayanos 2002; Vayanos 2004; Brunnermeier and Pedersen 2009). These forces can manifest themselves as investors' redemptions, margin calls, and the risk limits that are in place to preempt future capital calls. In addition, the occurrence of liquidity dry-ups simultaneously across asset types (Chordia, Sarkar, and Subrahmanyam 2005; Goyenko 2006; Goyenko and Ukhov 2009; Baele, Bekaert, and Inghelbrecht 2010) obliges constrained arbitrageurs to close some potentially profitable positions in order to undertake other trades with greater expected risk-adjusted returns.

We provide direct evidence of the primary role redemptions played in causing the selloffs. Redemptions account for roughly 50% of the average decline in hedge fund equity holdings during the selloff quarters (that is, they explain 6% of the 12% average decline in equity holdings). Because we can directly measure redemptions, this finding is the soundest evidence of the motives behind equity sales during the crisis. Moreover, we use hedge fund average leverage as a proxy for lender pressure and show that this channel alone accounts for about 42% of selloffs. Overall, redemptions and leverage explain about 80% of the decline in average hedge fund equity holdings (that is, 9.5% of the 12% average decline in equity holdings). We view this set of findings as consistent with the limits-of-arbitrage literature cited above.

To bring further evidence to light about the role played by financial constraints, we study the characteristics of the stocks that hedge funds traded during the crisis. We report that hedge funds were more likely to close positions in high- rather than low-volatility stocks. Symmetrically, short interest decreased more strongly for high-volatility stocks. These results reveal a potential risk management motive. As the limits-to-arbitrage literature predicts, a reduction in exposure to high-volatility assets can derive from margin calls (Brunnermeier and Pedersen 2009) or from internal risk management practices, such as Value at Risk (VaR) models (Vayanos 2004; Brunnermeier and Pedersen 2009). Interestingly, hedge funds were more likely to sell liquid stocks during the crisis,[5] consistent with Scholes's (2000) observation that, during a crisis, investors unwind their portfolios by selling the most liquid securities first. Moreover, hedge funds unwound their value and momentum strategies, consistent with a forced deviation from their standard strategies.

To give perspective to our findings about hedge funds, we compare their behavior with that of another important class of institutional investors, mutual funds. We show that mutual funds' equity portfolios did not significantly decrease during the financial crisis and that their redemptions were not nearly as severe as they were for hedge funds. This evidence calls for an investigation of the economic mechanisms that could make hedge funds more vulnerable

[5] Anand et al. (2010) make similar observations about trading during the crisis for the universe of institutions.

to external funding than are other institutional investors. Unlike hedge funds, mutual funds do not use leverage, have no restrictions on investors' liquidity, and in general cater to a less sophisticated clientele.

This observation suggests that investors in these two asset classes may react differently to negative performance, especially if they fear that hedge funds may lock up their money in case of further losses. Prior studies find a convex flow-performance relation for mutual funds (e.g., Chevalier and Ellison 1997; Sirri and Tufano 1998) and document that individual investors do not immediately liquidate their investments in mutual funds after initial losses (Calvet, Campbell, and Sodini 2009). In contrast, the flow-performance relation for hedge funds seems to be concave (in accordance with Li, Zhang, and Zhao 2011), especially in the presence of share restrictions (corresponding to the results of Ding et al. 2009). We combine these two separate strands of the literature and, in a pooled analysis of the flow-performance relation, document that, following poor past performance, hedge fund investors withdraw almost three times more capital as do mutual fund investors. We corroborate the evidence in Ding et al. (2009) by showing that a large part of the difference is due to hedge funds with illiquid shares relative to mutual funds. This result is consistent with the idea that the potential for hedge fund shares to become even more illiquid at times of crisis generates a preemptive response on the part of investors once poor performance is observed. We take this evidence as one key element in defining the different responses of mutual and hedge fund investors to the crisis. Hence, this element has the potential to explain at least part of the difference in the portfolio liquidation behavior of these two groups of institutional investors.

Finally, we examine the hypothesis that the observed difference in trading behavior also originates from mutual and hedge funds' different clienteles. Institutional investors in hedge funds are likely to be more sophisticated than individual investors in mutual funds. Calvet, Campbell, and Sodini (2009) provide evidence that investor sophistication magnifies the speed of reaction to news. Moreover, institutional investors have risk management controls in place to preempt violations of capital requirements. Also, managers employed by institutional investors have career concerns, as their compensation depends on the performance of the funds they select. Overall, these mechanisms are likely to make institutional investors more reactive to bad news than are individual investors. We test these conjectures by exploiting the heterogeneity in the client base of hedge funds (drawn from the ADV form database). We document that hedge funds with a higher share of institutional investors experienced stronger redemptions during the crisis and also sold more equity. This evidence establishes the prevalence of an institutional client base in hedge funds as another likely channel of the large redemptions hedge funds suffered and their consequent selloffs during the financial crisis.

Our results provide perspective on the findings of other recent research. Boyson, Stahel, and Stulz (2010) show that hedge funds display contagion across asset classes. Our results suggest that redemptions by investors and credit constraints are potentially important factors that could generate systematic contagion effects across asset types that are traded by hedge funds. Khandani and Lo (2011) hypothesize that the unprecedented losses of a number of long-short hedge funds in the summer of 2007 were the result of forced deleveraging. We show that this deleveraging actually occurred and that it was related to tightening financial constraints. By studying the correlation of hedge fund returns with the stock market, Cao et al. (2009) and Billio, Getmansky, and Pelizzon (2010) conclude that hedge funds are able to time the market and avoid liquidity dry-ups. Our evidence suggests that much of this "timing" behavior is the result of hedge fund capital evaporating during crises. Sadka (2010) shows that hedge fund returns contain a premium related to aggregate liquidity risk. Our evidence can explain this premium in terms of the financial constraints that prevent hedge funds from providing liquidity in times of crisis. Our finding that redemptions are a major constraint to hedge funds' ability to capture the illiquidity premium resonates with previous results showing that hedge funds' performance is affected by the amount of investor capital available to them (Hombert and Thesmar 2009; Teo 2011). Since the first draft of our article, Boyson, Helwege, and Jindra (2010) have analyzed similar data, but with a smaller set of hedge funds. They found that during the financial crisis, hedge funds sold more equity holdings than needed to merely face redemptions. Our work suggests that in addition to redemptions, a large part of the selloffs can be explained by hedge funds responding to lenders' pressure to deleverage.[6]

The article proceeds as follows. Section 1 describes the data sources we use. Section 2 explores the aggregate behavior of hedge funds during the crisis. Section 3 explores the financial constraints channel for the stock selloffs. Section 4 presents the comparative analysis of the flow-performance sensitivity relative to mutual funds and explores the channels for the observed difference in sensitivity. Section 5 concludes.

1. Data

1.1 Data sources and sample construction

Our study combines several datasets related to hedge funds, mutual funds, stocks, and institutional ownership.

[6] Also since our article, Brown, Green, and Hand (2010) have argued that fire sales were not a widespread phenomenon during the crisis because many funds did not experience negative alphas. In our view, the absence of negative alphas is not by itself evidence of a lack of fire sales, especially if the distress condition is reflected in the risk factors themselves. Rather, one can interpret the fact that hedge funds' inability to capture underpriced securities (testified to by the lack of positive alphas) as consistent with our finding of severe financial constraints for the hedge fund sector in a depressed equity market.

1.1.1 Hedge fund holdings data. The main dataset used in the study combines a list of hedge funds (by Thomson-Reuters), mandatory institutional quarterly portfolio holdings reports (13F), and information about hedge fund characteristics and performance (Lipper TASS Hedge Fund Database). The 13F mandatory institutional reports are filed with the Securities and Exchange Commission (SEC) on a calendar-quarterly basis and are compiled by Thomson-Reuters (formerly known as the 13F CDA Spectrum 34 database).[7] Form 13F requires all institutions with investment discretion of over $100 million at the end of the year to report their long holdings (mainly publicly traded equity, convertible bonds, and options) in the next year.[8] Therefore, all hedge funds with assets in such qualified securities in excess of $100 million are required to report their holdings in 13F filings. 13F reporting is done at the consolidated management company level.[9]

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. Relative to the self-reported industry lists commonly used to identify hedge funds, the Thomson-Reuters list is more comprehensive, as it classifies all 13F filers.[10] Moreover, the Thomson-Reuters hedge fund list identifies hedge funds at the disaggregated advisor level, not at

[7] 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…"

[8] Specifically with 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. More general 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.

[9] 13F filings have been used intensively for research concerning the role of institutional investors in financial markets. Sias, Starks, and Titman (2006) study the sources of correlation between institutional trades and returns. Brunnermeier and Nagel (2004) explore the behavior of hedge funds during the Internet bubble. Campbell, Ramadorai, and Schwartz (2009) combine 13F filings with intraday data to explore the behavior of institutional investors around earnings announcements.

[10] 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, dating back to when those reports were paper filings or microfiche in the public reference room. 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").

the 13F report consolidated level.[11,12] The 13F data available to us range from 1989:Q3 to 2009:Q4. Before applying the filters described below, the number of hedge funds in the Thomson-Reuters list varies from a few dozen in the early years to over 1,000 at the 2007 peak. With some caveats that we mention below, an additional advantage of 13F filings is that they are not affected 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).

Data in the 13F filings have a number of known limitations. First, small institutions that fall below the reporting threshold ($100 million in U.S. equity) at the end of the year are not in the sample the following year. Second, institutions are not required to report positions that do not make the threshold of $200,000 and 10,000 shares. Third, short equity positions are not reported. Fourth, the holding reports as collected by Thomson-Reuters are aggregated at the management company level. Nevertheless, as mentioned above, the Thomson-Reuters classification allows us to separately identify the advisors within the management company. Fifth, we only observe end-of-quarter snapshots on hedge fund holdings. Despite these limitations, it must be stressed that our data are not plagued by survivorship bias as they also contain the filings of defunct hedge fund companies.

Because many financial advisors manage hedge-fund-like operations alongside other investment management services, we need to apply a number of filters to the data to ensure that the hedge fund business is the main line of operation for the institutions in our sample. Therefore, we drop institutions that have advisors with a majority of non-hedge-fund business, even though such institutions have hedge funds that are managed in-house and included with their holdings in the parent management company's 13F report. Thomson-Reuters's hedge fund list also provides the classification of non-hedge-fund entities that file under the same 13F entity. We use 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 verify that large investment banks and prime brokers that might have internal hedge fund business are excluded from our list (e.g., Goldman Sachs Group, JP Morgan Chase & Co., American International Group Inc.). As a further filter, we

[11] For example, for Blackstone Group holdings in 13F data, Thomson-Reuters provides a classification of each of the advisors within Blackstone that reported their holdings in the same filing. 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 L.P. 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.

[12] As a shortcut, from now on we will refer to the observational unit in our dataset as a "hedge fund." It should be clear, however, that 13F provides asset holdings at the management firm level, or at the advisor entity level, when a management firm and its advisors are different entities. Each firm/advisor reports consolidated holdings for all the funds it has under management.

double-check the hedge fund classification by Thomson-Reuters against a list of ADV filings by investment advisors since 2006, when available.[13] We match those filings by advisor name to our 13F data. Then, following Brunnermeier and Nagel (2004) and Griffin and Xu (2009), we keep 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, which we label "pure-play" hedge funds. Our final sample covers 79.8% of the number of 13F institutions that have *any* hedge fund business, which makes 25.3% of their aggregate equity portfolio. The institutions that are excluded from our sample provide a variety of other asset management and trading services, such as wealth management advisory services and brokerage services.

We augment our data with hedge fund characteristics and monthly returns from the Thomson-Reuters's Lipper-TASS database (drawn in July 2010).[14] We use both the "Graveyard" and "Live" databases. We use hedge fund company names in TASS and map them 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 level. We aggregate the TASS data at the management company level on a quarterly frequency and match it to the 13F dataset using the consolidated management company name.[15] To avoid potential data errors, especially arising from the fact that not all funds report assets under management to TASS, we exclude management companies for which the ratio of 13F assets to assets under management from TASS exceeds ten. This filter drops about 8% of the observations. Further, we exclude hedge funds with less than $1 million in total assets under management (0.6% of the observations), in order to ensure that our results are not driven by hedge funds with insignificant holdings. As argued in the introduction, we focus on the years surrounding the recent financial crisis; our sample starts in the first quarter of 2004. The sample-end coincides with the end of the 13F data availability (2009:Q4). Finally, for the fund-level regressions, we winsorize fund flows and changes in hedge fund equity holdings at the 5^{th} and 95^{th} percentiles within each quarter, as the distributions of these variables have fat tails.

[13] All current advisor ADV filings are available on the SEC's investment advisor public disclosure website: http://www.adviserinfo.sec.gov. The ADV filings were mandatory for all hedge funds only for a short time in 2006. After that point, they were filed on a voluntary basis.

[14] While we use a recent TASS data feed (July 2010) in our analysis, we use an older version (August 2007) to identify firms (because it includes hedge fund names).

[15] We use strategy assets under management as weights in aggregating fund characteristics and total reported returns.

Panel A of Table 1 provides annual statistics for our sample of hedge funds. The first three columns show a rapid increase in the number of hedge funds and assets under management (AUM) up to 2007. The subsequent decline in the number of matched TASS funds and AUM is consistent with the recent patterns of hedge fund liquidations at the end of 2008 and in the first three quarters of 2009. The slow increase in the number of 13F funds in 2008–2009 (Column 1) is due to smaller new funds that do not report to TASS. According to Hedge Fund Research Inc., the total assets managed by hedge funds had, by 2009, decreased by around 19% due to the market crisis and the record-setting hedge fund closures in 2008 and 2009.[16] This pattern is strongly reflected in Figure 1, which plots hedge fund equity holdings over time as a fraction of the total market capitalization. Panel A in Table 1 also provides summary statistics on quarterly portfolio turnover. 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 q divided by the total holdings at the end of quarter $q-1$, where buys and sells are measured with end-of-quarter $q-1$ prices. This definition of turnover captures trading unrelated to inflows or outflows. Because it is computed from quarterly snapshots, it is understated, but it nevertheless provides an important assessment of the relevance of quarterly holdings data. The average quarterly turnover in the sample is 39.4%. The magnitude of the turnover in our data is comparable to that found by Brunnermeier and Nagel (2004), and is higher than the 18.2% (quarterly) turnover for mutual funds in 1994 found by Wermers (2000) and the 14.2% quarterly turnover for the mutual funds in our sample. Despite the high turnover, a substantial part of the 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.

1.1.2 Short interest data. 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 over the 2004:Q1–2009:Q4 period provided by the exchanges. These data are reported on a monthly basis at the stock level (preventing us from identifying the investors who hold the short positions). In our empirical analysis, we make the simplifying assumption that short interest is mainly driven by arbitrageurs, among which hedge funds play an important part. This assumption is supported by Boehmer and Jones (2008), who document that 55% to 70% of all short-selling transactions are performed by institutions (Table 5 in their paper). A recent research report by Goldman Sachs (2010) estimates that as of March 2010, hedge funds account for 85% of short

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

Table 1
Summary statistics

Panel A: Hedge-fund level, by year

	Number of Mgrs		Total AUM	Equity portfolio ($m, TASS match)	Equity portfolio ($m, whole sample)			Number of Stocks per manager			Quarterly portfolio turnover		
Year	13F	TASS match	in TASS ($bn)	Mean	Mean	Median	St. dev.	Mean	Median	St. dev.	Mean	Median	St. dev.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
2004	436	104	93	466	754	254	1,810	104	47	197	0.45	0.40	0.32
2005	530	124	112	597	851	279	1,996	105	45	215	0.42	0.38	0.28
2006	606	133	147	747	901	259	2,286	106	41	235	0.42	0.38	0.29
2007	693	136	189	910	1011	286	2,762	102	38	228	0.41	0.37	0.29
2008	696	114	149	610	667	164	1,872	80	29	203	0.33	0.29	0.25
2009	621	98	147	521	611	139	1,605	81	29	200	0.47	0.40	0.41

(*continued*)

Table 1
Continued

Panel B: Aggregate level, quarterly frequency

	N	Mean	St.Dev.	Min	Median	Max
HF holdings over mkt cap (%)	24	2.420	0.549	1.460	2.500	3.190
Δ HF Holdings (%, share of equity holdings)	24	3.390	8.010	−16.700	4.500	13.900
Δ Holdings (%, share of mkt cap)	24	0.066	0.199	−0.489	0.118	0.336
MF holdings over mkt cap (%)	24	13.400	0.799	12.200	13.500	14.700
Δ MF Holdings (%, share of mkt cap)	24	0.077	0.096	−0.094	0.067	0.296
Other inst. holdings over mkt cap (%)	24	40.900	2.010	34.100	40.600	44.500
Δ Other inst. holdings (%, share of mkt cap)	24	−0.005	0.934	−2.370	0.202	1.620
Non-institutional holdings over mkt cap (%)	24	43.300	2.130	39.900	43.100	50.800
Δ Non-institutional holdings (%, share of mkt cap)	24	−0.138	0.879	−1.360	−0.331	2.330
Short interest ratio (SIR) (%)	24	2.0740	0.515	2.090	2.660	3.830
Δ Short interest ratio (Δ SIR) (%, share of short interest)	24	1.180	8.740	−20.700	1.340	19.800
Δ Short interest ratio (Δ SIR) (%, share of shares outstanding)	24	0.041	0.260	−0.605	0.029	0.676

CORRELATIONS		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
HF holdings over mkt cap (%)	(1)	1.00											
Δ HF Holdings (%, share of equity holdings)	(2)	0.10	1.00										
Δ Holdings (%, share of mkt cap)	(3)	0.24	0.97	1.00									
MF holdings over mkt cap (%)	(4)	−0.22	0.17	0.13	1.00								
Δ MF Holdings (%, share of mkt cap)	(5)	−0.18	0.43	0.38	0.32	1.00							
Other inst. holdings over mkt cap (%)	(6)	0.48	−0.39	−0.27	−0.41	−0.44	1.00						
Δ Other inst. holdings (%, share of mkt cap)	(7)	−0.16	−0.26	−0.25	0.18	−0.38	0.10	1.00					
Non-institutional holdings over mkt cap (%)	(8)	−0.63	0.28	0.15	0.07	0.34	−0.91	−0.12	1.00				
Δ Non-institutional holdings (%, share of mkt cap)	(9)	0.13	0.01	0.00	−0.26	0.21	0.00	−0.96	0.06	1.00			
Short interest ratio (SIR) (%)	(10)	0.58	−0.29	−0.23	−0.54	−0.34	0.66	−0.28	−0.57	0.39	1.00		
Δ Short interest ratio (Δ SIR) (%, share of short interest)	(11)	0.18	0.42	0.42	0.13	0.16	−0.13	−0.49	0.02	0.40	0.23	1.00	
Δ Short interest ratio (Δ SIR) (%, share of shares outstanding)	(12)	0.20	0.43	0.42	0.07	0.13	−0.10	−0.48	0.02	0.40	0.27	0.99	1.00

(*continued*)

Table 1
Continued

Panel C: Hedge-fund level, quarterly frequency

	N	Mean	St.Dev	Min	Median	Max
Δ HF Holdings (%, share of equity holdings)	2,634	10.600	43.300	−76.700	3.290	294.000
Buys (%, share of equity holdings)	2,634	50.700	45.400	0.068	38.400	367.000
Sales (%, share of equity holdings)	2,634	40.400	22.400	0.595	38.700	98.800
Fund flows (%, share of AUM)	2,595	0.423	14.600	−49.700	0.285	88.800
Hedge Fund total return (%)	2,648	1.960	7.820	−43.000	1.970	68.700
Hedge Fund abnormal return (%)	1,489	−0.005	0.044	−0.266	−0.005	0.369
Equity portfolio return (%)	2,648	0.025	0.148	−0.814	0.026	2.680
Equity portfolio size (log(assets))	2,634	19.100	1.530	10.900	19.200	24.700
Assets under management (log(AUM))	2,648	19.900	1.450	14.200	19.900	24.800
Avg leverage	1,725	0.793	0.861	0.000	0.500	3.000
Multiasset strategy dummy	2,452	0.241	0.428	0.000	0.000	1.000
Standard deviation of past-one-year returns	2,334	0.052	0.048	0.000	0.037	0.472
Lockup period	2,648	6.700	7.000	0.000	5.470	49.200
Long redemption period dummy	2,648	0.833	0.373	0.000	1.000	1.000
Poor relative performance dummy	2,603	0.250	0.433	0.000	0.000	1.000
Age (in quarters since first 13F filing)	2,648	18.500	15.500	1.000	14.000	80.000

CORRELATIONS		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
Δ HF Holdings (%, share of equity holdings)	(1)	1.00															
Buys (%, share of equity holdings)	(2)	0.86	1.00														
Sales (%, share of equity holdings)	(3)	−0.19	0.32	1.00													
Fund flows (%, share of AUM)	(4)	0.08	0.04	−0.05	1.00												
Hedge Fund total return (%)	(5)	0.09	0.02	−0.12	−0.04	1.00											
Hedge Fund abnormal return (%)	(6)	0.10	0.10	0.02	−0.14	0.61	1.00										
Equity portfolio return (%)	(7)	0.07	0.00	−0.09	0.04	0.58	0.20	1.00									
Equity portfolio size (log(assets))	(8)	−0.24	−0.34	−0.17	0.01	−0.02	−0.04	−0.02	1.00								
Assets under management (log(AUM))	(9)	0.00	−0.03	−0.04	0.12	−0.02	0.02	−0.05	0.53	1.00							
Avg leverage	(10)	0.10	0.20	0.24	−0.07	−0.04	0.05	−0.04	−0.26	−0.11	1.00						
Multiasset strategy dummy	(11)	0.11	0.21	0.22	0.05	−0.04	0.02	−0.02	−0.16	0.24	0.43	1.00					
Standard deviation of past-one-year returns	(12)	−0.18	−0.19	−0.04	−0.10	0.00	−0.01	0.01	−0.01	−0.14	−0.03	−0.15	1.00				
Lockup period	(13)	−0.09	−0.12	−0.06	0.00	0.02	−0.04	−0.01	−0.21	−0.14	−0.12	−0.26	0.10	1.00			
High redemption period dummy	(14)	0.01	0.04	0.07	−0.04	0.05	−0.01	0.01	−0.12	−0.11	0.03	−0.01	−0.06	0.27	1.00		
Poor relative performance dummy	(15)	−0.04	0.03	0.12	−0.11	−0.39	−0.28	−0.12	−0.08	−0.12	0.09	0.02	0.08	−0.05	−0.08	1.00	
Age (in quarters since first 13F filing)	(16)	−0.11	−0.11	−0.02	−0.10	−0.07	−0.02	−0.09	0.21	0.06	−0.16	0.07	0.16	−0.08	−0.05	0.04	1.00

(*continued*)

Table 1
Continued

Panel D: Stock level, quarterly frequency

	N	Mean	St.Dev	Min	Median	Max
Total hedge fund holdings (%)	102,406	7.427	9.307	0.000	4.112	100.000
Δ Total hedge fund holdings (%)	97,111	0.095	1.997	−6.911	0.000	8.184
Short interest ratio (SIR) (%)	100,873	4.257	5.884	0.000	2.232	97.287
Δ Short interest ratio (SIR) (%)	99,358	0.072	2.448	−87.192	0.001	87.197
Volatility	94,981	0.127	0.078	0.000	0.108	0.500
Amihud ratio	98,208	0.638	1.408	0.000	0.016	5.000
Size ($ million)	100,052	3050.647	14740.464	0.253	318.086	513362.000
Book-to-market	96,108	0.762	2.058	0.000	0.501	238.798
Past 6m ret	97,059	0.010	0.462	−0.978	−0.009	65.056

CORRELATIONS		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Total hedge fund holdings (%)	(1)	1.00								
Δ Total hedge fund holdings (%)	(2)	0.15	1.00							
Short interest ratio (SIR) (%)	(3)	0.22	0.00	1.00						
Δ Short interest ratio (SIR) (%)	(4)	0.03	0.10	0.23	1.00					
Volatility	(5)	0.10	0.00	0.06	−0.04	1.00				
Amihud ratio	(6)	−0.15	−0.02	−0.30	−0.01	0.09	1.00			
Size ($ million)	(7)	−0.09	0.00	−0.06	0.00	−0.15	−0.09	1.00		
Book-to-market	(8)	−0.02	−0.02	−0.04	−0.02	0.04	0.14	−0.04	1.00	
Past 6m ret	(9)	−0.01	0.03	−0.01	0.07	0.06	−0.01	0.02	−0.13	1.00

Table 1
Continued
Panel E: Flow-performance regressions, quarterly frequency

	N	Mean	St.Dev	Min	Median	Max
Fund flows	204,240	0.062	0.357	−0.677	0.000	2.608
TRank1	204,240	0.276	0.098	0.000	0.333	0.333
TRank2	204,240	0.168	0.148	0.000	0.172	0.333
TRank3	204,240	0.058	0.098	0.000	0.000	0.333
TRank1 (within style)	204,240	0.277	0.097	0.000	0.333	0.333
TRank2 (within style)	204,240	0.168	0.147	0.000	0.170	0.333
TRank3 (within style)	204,240	0.057	0.097	0.000	0.000	0.333
I(Hedge fund)	204,240	0.494	0.500	0.000	0.000	1.000
I(HF with constraints)	204,240	0.261	0.439	0.000	0.000	1.000
log(AUM)	204,238	4.269	2.197	−29.934	4.301	12.329

CORRELATIONS		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Fund flows	(1)	1.00									
TRank1	(2)	0.03	1.00								
TRank2	(3)	0.05	0.67	1.00							
TRank3	(4)	0.07	0.35	0.66	1.00						
TRank1 (within style)	(5)	0.03	0.94	0.65	0.34	1.00					
TRank2 (within style)	(6)	0.05	0.65	0.95	0.64	0.66	1.00				
TRank3 (within style)	(7)	0.06	0.34	0.65	0.91	0.34	0.66	1.00			
I(Hedge fund)	(8)	−0.03	−0.02	0.01	0.02	0.00	0.01	0.01	1.00		
I(HF with constraints)	(9)	−0.01	0.03	0.03	0.01	0.02	0.03	0.02	0.60	1.00	
log(AUM)	(10)	−0.04	0.08	0.04	−0.01	0.08	0.03	−0.01	−0.31	−0.13	1.00

Returns by Type of Institution and Return Ranking	*N*	Mean	St.Dev	Min	Median	Max
Entire distribution of Returns:						
Mutual Funds	103,422	0.008	0.097	−0.777	0.017	0.241
Hedge Funds	100,818	0.011	0.077	−1.000	0.015	0.243
Return ranking in 1st tercile:						
Mutual Funds	34,456	−0.038	0.101	−0.777	−0.014	0.141
Hedge Funds	34,359	−0.046	0.080	−1.000	−0.021	0.034
Return ranking in 2nd tercile:						
Mutual Funds	34,479	0.009	0.084	−0.246	0.018	0.188
Hedge Funds	31,002	0.008	0.032	−0.105	0.014	0.058
Return ranking in 3nd tercile:						
Mutual Funds	34,487	0.054	0.083	−0.199	0.051	0.241
Hedge Funds	35,457	0.069	0.058	−0.046	0.055	0.243

Table 1
Continued

Panel F: ADV data, quarterly frequency

	N	Mean	St.Dev.	Min	Median	Max
Individual	1,614	1.750	7.869	0.000	0.000	88.000
High net worth individual	1,614	5.582	15.036	0.000	0.000	88.000
Bank	1,614	0.300	1.234	0.000	0.000	8.438
Mutual fund	1,614	0.963	3.148	0.000	0.000	20.353
Pension fund	1,614	2.567	8.375	0.000	0.000	63.000
Other pooled investment vehicle	1,614	71.545	24.040	0.000	88.000	88.000
Endowment	1,614	1.420	5.462	0.000	0.000	38.000
Corporation	1,614	4.532	9.751	0.000	0.000	48.176
Government	1,614	0.447	1.923	0.000	0.000	32.118
Other	1,614	2.884	10.129	0.000	0.000	63.000
Institutional ownership	1,614	10.582	2.392	0.000	11.000	13.875

CORRELATIONS		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Individual	(1)	1.00										
High net worth individual	(2)	0.46	1.00									
Bank	(3)	0.39	0.35	1.00								
Mutual fund	(4)	0.11	0.02	0.09	1.00							
Pension fund	(5)	0.07	0.12	0.03	0.26	1.00						
Other pooled investment vehicle	(6)	−0.46	−0.71	−0.24	−0.22	−0.37	1.00					
Endowment	(7)	0.04	0.22	0.04	−0.02	0.11	−0.30	1.00				
Corporation	(8)	−0.07	−0.03	−0.05	0.09	0.05	−0.26	−0.07	1.00			
Government	(9)	0.02	0.00	0.02	0.06	0.16	−0.15	0.03	0.28	1.00		
Other	(10)	−0.06	−0.10	−0.07	0.05	−0.05	−0.24	−0.07	−0.12	−0.07	1.00	
Institutional ownership	(11)	−0.56	−0.82	−0.25	0.08	0.06	0.68	−0.12	0.16	0.11	0.13	1.00

The table presents summary statistics for the data used in the study. The sample period is 2004:Q1 to 2009:Q4. Panel A presents time-series summary statistics at the hedge-fund level, by year. Panel B presents summary statistics for the hedge fund holdings sample, aggregated at the calendar quarter level. Panel C provides summary statistics for the hedge-fund-level variables, conditioned on a successful match with TASS. Panel D presents summary statistics for the hedge fund holdings sample, aggregated at the stock-quarter level. Panel E provides summary statistics for the data used in the flow-performance regressions. Panel F has summary statistics on percentage ownership by different investor groups in the ADV data.

positions. Moreover, even if hedge funds conduct no short selling, their long trading can drive short activity through their counterparty. For example, if a hedge fund takes a bearish bet on the stock market by using put options, the sellers of these contracts would typically hedge their bets and eventually generate short interest. The validity of our working assumption is also supported by the similar behavior of aggregate short interest and hedge fund holdings over time (compare Figures 1 and 2; the correlation of the quarterly changes is 0.42). Furthermore, aggregate short-selling activity is quite small in magnitude, even in recent years, which suggests that only a small group of specialized arbitrageurs engage in it.

1.1.3 Mutual fund data. In Section 4, we compare the response of hedge fund flows to past performance and the equivalent response for mutual funds. We use the CRSP Mutual Fund Database to calculate the total mutual fund assets and flows for all U.S. equity mutual funds with assets invested primarily in U.S. equities. To select our sample of U.S. equity mutual funds, we first screen share classes with equity group codes or the Lipper Asset Code=EQ or with 50% or more of their assets invested in common stocks. Then, we identify and drop all global or international funds using the Lipper Class and Objective Code variables. Also, we eliminate mutual fund names with

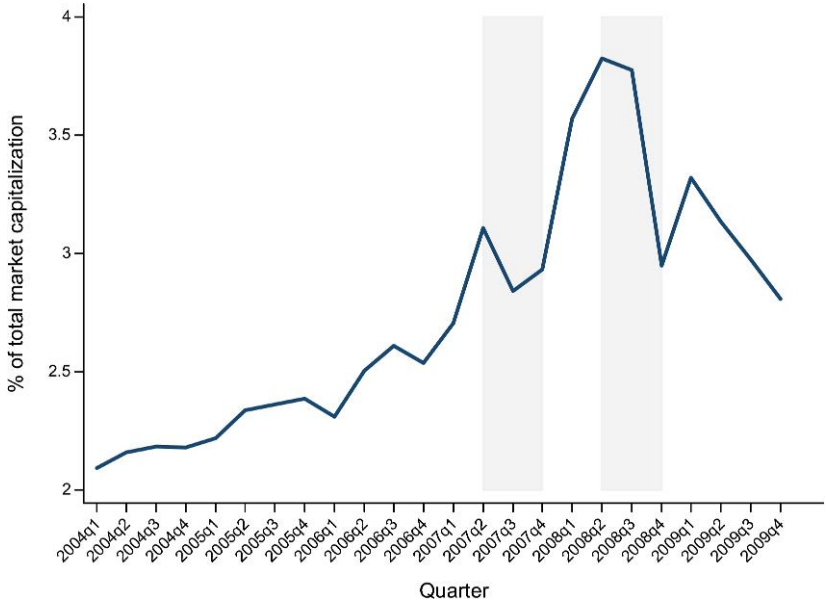

Figure 2
Time series of aggregate short interest (% of total market capitalization)
The figure plots the fraction of U.S. stock market capitalization corresponding to the total open short interest as provided by the exchanges. The shaded areas denote the quarters around the Quant Meltdown (2007:Q3-Q4) and the Lehman Brothers' Bankruptcy (2008:Q3-Q4). The series ranges from 2004:Q1 to 2009:Q4.

Global, International, Europe, and Emerging strings. We derive net flows using share class return and asset time-series information. Next, we use MFLINKS and the CRSP fund-to-portfolio map to construct mutual fund characteristics (returns, expenses, turnover, retail, etc.) at the portfolio level using share class assets as weights. We designate as retail share classes all share classes that are not institutional. Finally, we aggregate asset and flow information every month.

1.2 Summary statistics

Additional summary statistics for the datasets used in the study are reported in the remaining panels of Table 1. Variable definitions are provided in the Appendix. Panel B of Table 1 focuses on the time series of the aggregate variables. The table shows that the selected hedge funds hold, on average, 2.42% of the entire stock market capitalization, peaking at 3.19% (in the second quarter of 2007). The short interest ratio averages 2.74%, peaking at 3.83% (in the second quarter of 2008). The fraction of market capitalization held by hedge funds is of a smaller order of magnitude than that held by other investor groups. This fact partly depends on our choice to restrict the sample to pure-play hedge funds, as described above. In a recent study, Billio et al. (2010) also find that total hedge fund assets are much smaller than the assets of other institutions (banks, brokers, and insurers).

We are interested in active changes in hedge funds' equity holdings that result from actual trading, not from price changes. To this end, we evaluate the quarterly trades made by each fund at the previous period prices and aggregate them across the funds in the sample in a given quarter. Then, we divide these dollar trades by either the total hedge fund equity holdings in the previous quarter or the total market capitalization in the previous quarter.[17] The choice of previous-quarter prices allows us to focus on changes in equity holdings that are due to trades, not to price changes. Panel B presents summary statistics of the aggregate changes in investor holdings, as well as a correlation table; the average quarterly change in the total hedge fund holdings is 3.39% of their total equity holdings, or 0.066% of the total market capitalization.

Panel C of Table 1 presents summary statistics for the hedge-fund-quarter-level data. In some of the hedge-fund-level analysis below, the dependent variable is the fraction of the fund equity portfolio that is traded over the quarter. To construct this variable, we aggregate the quarterly changes in holdings for all stocks in the fund portfolio and evaluate them at the previous quarter's prices. Then the total dollar value of the trades is divided by the

[17] We first adjust shares held for splits and distributions. We then 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. For this reason, we require hedge funds to appear in two consecutive quarters. When a hedge fund does not report (because it is below the $100 million assets-under-discretion cutoff), we eliminate the observation (as opposed to reporting a large drop in holdings). 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.wharton.upenn.edu/.

value of the equity portfolio in the previous quarter. Again, the choice of prior-quarter prices avoids the introduction of bias due to the change in prices over the quarter. The average percentage change in hedge funds' equity portfolios is 10.60%. We construct equity portfolio returns in a given quarter by assuming that changes in reported 13F positions occur at end-of-quarter prices. The hedge-fund-quarter data is matched with TASS, as explained above. We use the TASS data to construct total returns by aggregating the returns of funds within each management company (weighted by the size of assets under management of each fund in the company). Following the standard in the literature (e.g., Chevalier and Ellison 1997; Sirri and Tufano 1998; Agarwal, Daniel, and Naik 2009), we compute quarter q fund flows as the quarterly difference in AUM minus the dollar return on quarter $q - 1$ AUM. Fund flows are then scaled by the lagged AUM. For leverage, we use the TASS average leverage variable (which is defined as debt over AUM) and average it at the company level using the fund-level AUM as weights. The mean leverage is 0.79. We describe the other variables as we use them in the analysis.

Panel D of Table 1 presents summary statistics for the stock-quarter-level sample. For stock characteristics, we use CRSP and Compustat. The dependent variable that we use in our stock-level regressions is the change in the number of a firm's shares held by hedge funds aggregated across all hedge funds in our sample divided by the total number of shares outstanding for that firm. Across stocks, this figure averages 0.095%. Focusing on the level of stock ownership, hedge funds hold 7.43% of a firm's equity, on average. From the comparison with the aggregate holdings in Panel B, which are weighted by market capitalization, it appears that hedge funds' equity holdings are tilted toward 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. Following Amihud (2002), stock liquidity is measured by the average ratio of the absolute value of daily returns to daily volume in the quarter. Size is the market capitalization at the beginning of the quarter. Book-to-market (BM) is computed as the ratio of the latest book value from annual statements to the latest market value at the beginning of the quarter. Finally, we construct the past-six-month cumulative return at the beginning of the quarter to capture momentum.

Finally, Panels E and F of Table 1 present summary statistics for the variables used in the flow-performance analysis and for hedge fund ownership from the ADV filings, respectively.

2. Hedge Fund Trading During the Financial Crisis

2.1 Aggregate long hedge fund holdings

Our first goal is to characterize hedge fund behavior during the financial crisis. For the analysis in this section, we apply all the sample selection criteria described in Section 1, except that we do not require a valid TASS match.

The result is a broad sample that is highly representative of the hedge fund universe.

As discussed above, Figure 1 suggests that in correspondence with two notable events during the crisis period (the Quant Meltdown and the fall of Lehman Brothers), hedge funds' stock market participation decreased drastically. Of course, this evidence is affected by relative changes in market prices, which confound the pure effect of trading. For this reason, in the remainder of the article we focus directly on actual trades evaluated at prior-quarter prices.

In Table 2, we present the quarter-by-quarter change in hedge fund holdings. We break down the 2004–2009 sample period as follows: a pre-crisis period (2004:Q1 to 2007:Q2) associated with the bull market and the expansion of the hedge fund industry; a crisis period (2007:Q3–2009:Q1), which begins with the Quant Meltdown in the summer of 2007 (see Khandani and Lo 2011) and ends with the trough of the stock market in March 2009; and a post-crisis period (2009:Q2–2009:Q4). This classification of quarters is of course done ex post. The main objective is to identify the regime shift in hedge fund investing behavior across the different periods. The table shows that during the pre- and post-crisis periods, hedge funds increased their aggregate stock equity portfolio by about 6% per quarter. During the crisis, however, hedge funds reduced their stock holdings by 3% each quarter, on average. The quarter-by-quarter breakdown reveals that the withdrawals were concentrated in four quarters: the third and fourth quarters of 2007 and of 2008. We define these quarters as "selloff quarters." In particular, in the third and fourth quarters of 2007, hedge funds sold about 9.9% and 2.7% of their aggregate equity

Table 2
Hedge fund trading

		Avg Qtr Δ Holdings Hedge Funds	
		%	% of total mktcap
		(1)	(2)
Pre-crisis	2004Q1-2007Q2	6.13	0.13
Crisis	2007Q3-2009Q1	−3.06	−0.10
Post-crisis	2009Q2-2009Q4	5.60	0.17
Selloff quarter	2007Q3	−9.87	−0.31
Selloff quarter	2007Q4	−2.74	−0.08
	2008Q1	4.72	0.13
	2008Q2	3.57	0.10
Selloff quarter	2008Q3	−16.70	−0.49
Selloff quarter	2008Q4	−14.26	−0.33
	2009Q1	13.88	0.25

The table reports the average quarterly changes in aggregate hedge fund holdings during selected subperiods. In Column 1, the variable of interest is the percentage change in aggregate hedge fund holdings between two quarters. In Column 2, the variable of interest is the change in hedge fund holdings as a percentage of the total market capitalization, using prior-quarter prices to evaluate the trades. To be included in the sample, a hedge fund must have equity holdings in both quarters. The sample period is 2004:Q1 to 2009:Q4, which gives 24 quarterly observations for each variable.

portfolio, respectively, while in the third and fourth quarters of 2008, they cut their holdings by a compounded value of 29%, about 16.7% and 14.3% in each quarter, respectively.[18]

Table 2 also presents the magnitude of the withdrawal in terms of the percentage of the total market capitalization. In the worst quarters of 2008, the net value of hedge fund stock sales corresponded to -0.49% and -0.33% of the total market capitalization. Because the pure-play hedge funds examined here hold only a small fraction of market capitalization, their selling pressure appears to be small in magnitude relative to the total market capitalization.

Although a study of the effect of the observed trades on market prices is beyond the scope of this work, it is worth pointing out 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, equilibrium is fragile.[19] That is to say, small shocks to the net supply of assets can cause drastic price changes. Also important to note, the observed selloffs can be concentrated in a few assets that are more likely to be held by arbitrageurs in normal times. In such a case, the losses in hedge fund capital and the consequent drop in liquidity provision are likely to have more of a significant impact than they would on a well-diversified portfolio. The stock-level analysis in Section 3 confirms that the selloffs that took place were primarily in high-volatility stocks.

This novel stylized fact, that hedge funds massively exited the stock market during some crisis quarters, sheds light on the literature's previous findings. First, Cao et al. (2009) find that hedge fund returns are less correlated with stock market returns around crises. Our main result shows that the low correlation results from lower participation in the stock market. Second, Ang, Gorovyy, and van Inwegen (2010) find that hedge funds started reducing their leverage prior to the financial crisis of 2008, as early as 2007. Our evidence confirms this early deleveraging by showing that it affected their long U.S. equity portfolio holdings substantially.

In the Online Appendix, we discuss two cross-sectional patterns in the data. First, we document the distribution of hedge fund trades within each quarter. We find that during the third and fourth quarters of 2008, nearly a quarter of hedge funds sold more than 40% of their equity holdings. This selloff was not compensated for with an increase in the fraction of other hedge funds buying stocks. Second, we present an exit-reentry matrix that shows that about half of the hedge funds that sold substantial fractions of their portfolios during the crisis returned to the stock market within two quarters.

---

[18] Notice that while Figure 1 does not show a drop in stock market participation in the fourth quarter of 2007, the decrease in the hedge fund portfolio is evident from Table 2. The difference in the two statistics results from the fact that the ratio in Figure 1 is affected by the change in market prices in both the numerator and denominator. To filter out this effect, one needs to rely on Table 2, which focuses on trades evaluated at prior-period prices.

[19] Coval and Stafford (2007) and Hau and Lai (2011) find that fire sales affect the prices of other securities held by the same entities.

2.2 Aggregate short interest

There is a chance that the selling pressure on hedge funds during this period was mitigated by the contemporaneous closing of hedge funds' short positions. Brunnermeier and Pedersen (2009) show that limits-to-arbitrage can constrain speculators' positions on the long as well as short sides. Hence, we need to examine whether the unwinding of short positions, if occurred, overlapped with the stock selloffs that we have documented so far. As noted above, we rely on Boehmer and Jones (2008) and Goldman Sachs (2010) and assume that the short interest reported by the exchanges is highly correlated with hedge fund short positions. Indeed, comparing the charts of aggregate hedge fund holdings (Figure 1) and aggregate short interest (Figure 2) suggests that the two variables display similar patterns.

In Table 3, Panel A, we present the average changes in short interest during the three periods we examine, as well as a quarter-by-quarter breakdown. The panel shows that the aggregate short interest changed by 2.3%, 2.7%, and −7.8%, during the pre-crisis, crisis, and post-crisis periods, respectively. During the crisis, there was great time-series variation in the aggregate short interest. Most notable are the increase of 19.8% following the fall of Bear Sterns in the first quarter of 2008 and the decline of 20.7% following the short-selling ban in the last quarter of 2008. Finally, there was a surge in short interest in the first quarter of 2009, the same period in which market prices bottomed and hedge funds returned to the market (see the increase in hedge funds' equity holdings in Table 2). This observation is consistent with the evidence of Lamont and Stein (2004), that short interest is negatively correlated with past market returns.

The comparison between Table 2 and Table 3, Panel A, confirms the impression from Figures 1 and 2. To a large extent, aggregate hedge fund equity holdings and aggregate short interest moved in tandem, especially during the financial crisis. The correlation between the changes in Table 2, Column 2, and Table 3, Panel A, Column 2, is 0.59 (p-value = 0.07) in the entire sample; it rises to 0.79 (p-value = 0.03) in the crisis period. This evidence provides some intuition on the channels behind the equity selloffs. Rather than shifting from long to short positions in a bearish run, hedge funds unloaded both sides of their balance sheets. The next sections of the article provide more insight into the ultimate causes of this deleveraging.

As for the issue of whether hedge fund actions caused an order imbalance and consequent price pressure, we want to measure whether closing short positions compensated for unwinding long ones. This situation seems unlikely because hedge funds are typically long and short in different stocks. Still, we explore this possibility by means of a stock-level analysis. In Table 3, Panel B, we regress quarterly changes in hedge fund stock-level ownership on quarterly changes in stock-level short interest and its interaction with the selloff quarter dummy. We find that while the correlation between hedge fund

Table 3
Short-selling activity and investments by other investors

Panel A: Aggregate short interest and other investors

		Avg Qtr Δ Short Interest		Avg Qtr Δ Holdings (% of total mkt cap)		
		%	% of total mktcap	Mutual funds	Other institutions	Non-instit. investors
		(1)	(2)	(3)	(4)	(5)
Pre-crisis	2004Q1-2007Q2	2.33	0.06	0.22	0.26	−0.55
Crisis	2007Q3-2009Q1	2.71	0.10	−0.02	−0.02	0.25
Post-crisis	2009Q2-2009Q4	−7.75	−0.21	0.07	0.58	−1.03
	2007Q3	−5.65	−0.16	0.13	1.85	−1.82
	2007Q4	7.49	0.21	0.17	−2.06	2.19
	2008Q1	19.84	0.68	−0.01	0.28	0.27
	2008Q2	7.90	0.29	−0.61	0.15	0.64
	2008Q3	−2.10	−0.07	−0.01	0.01	0.42
	2008Q4	−20.69	−0.61	−0.03	1.30	−1.54
	2009Q1	12.18	0.39	0.22	−1.66	1.57

(*continued*)

Table 3
Continued

Panel B: Stock-level long hedge fund holdings on short interest

	Dependent variable: Δ HF holdings (%)			
	(1)	(2)	(3)	(4)
Δ Short interest	0.071***	0.071***	0.071***	0.071***
	(8.382)	(11.173)	(10.659)	(13.354)
× Selloff quarter	0.022	0.021**		
	(0.909)	(2.026)		
Selloff quarter	−0.449 * *	−0.402***		
	(−2.225)	(−21.630)		
FirmFE	No	Yes	No	Yes
Quarter FE	No	No	Yes	Yes
Observations	103982	103982	103982	103982
Adj. R^2	0.017	0.016	0.029	0.028
Number of stocks	6242	6242	6242	6242

Panel A reports the average quarterly changes in aggregate short interest as well as the changes in other investor aggregate holdings in selected subperiods. In Column 1, the variable of interest is the percentage change in aggregate short interest between two quarters. In Column 2, the variable of interest is the change in short interest as a percentage of the total market capitalization, using prior-quarter prices to evaluate the short interest. In Columns 3–5, the variable of interest is the change in aggregate holdings by mutual funds, other institutions, and non-institutional investors, respectively. The change in holdings by non-institutional investors is determined as the complement to zero of the change in holdings of other institutions minus the change in short interest. Panel B reports estimates from OLS stock-level regressions of the % change in hedge fund holdings (as a fraction of prior-period holdings, evaluated at prior-period prices) on the stock-level change in % of short interest (as a fraction of shares outstanding). In Columns 1 and 2, the Selloff quarters are 2007:Q3–Q4 and 2008:Q3–Q4. Standard errors are clustered at the quarter level in Columns 1 and 3, and at the stock level in Columns 2 and 4. *t*-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 20041 to 20094, which gives 24 quarterly observations for each variable.

trading and short selling is positive and statistically significant, the coefficient is low: around 7.1% across specifications. We also examine the effect in selloff quarters (Q3, Q4 of 2007 and Q3, Q4 of 2008). The correlation of hedge fund trades and changes in short interest is higher in these quarters by 2.1%. The results do not change when we include stock fixed effects (Column 2) or when we replace the selloff quarter dummy with time fixed effects (Columns 3 and 4). To illustrate the economic magnitude, for a 1% decline in short interest in a particular stock, hedge fund holdings decrease by 0.09% in a selloff quarter, on average. That is, only 9% of hedge funds' stock sales are made up for by unwinding short positions. We find this result to be intuitive, given that hedge funds' long and short positions do not typically overlap.

2.3 The other side of hedge fund trades

Since hedge funds reduced their equity participation during the financial crisis, we would like to know who bought their shares. In Table 3, Panel A, we repeat the analysis from Table 2 (Column 2) for other groups of investors: mutual funds, other non-mutual-fund institutions (excluding hedge funds), and non-institutional investors. The changes in the holdings of mutual funds and other institutions are also identified using the 13F filings. First, for each stock, we determine the change in the holdings of non-institutional investors as the complement to zero of the changes in institutional holdings minus the change in short interest. Then, the stock-level changes, evaluated at prior-quarter prices, are aggregated and divided by stock market capitalization in the prior quarter to obtain the aggregate change in non-institutional holdings.[20]

The general picture from Panel A in Table 3 is that other types of investors did not exit the stock market in the same fashion that hedge funds did. We observe that mutual funds reduced their holdings throughout 2008, but these trades represent a smaller fraction of their holdings. The holdings of other institutional investors appear volatile over the crisis period. They sold stocks in 2007:Q4 and 2009:Q1. Interestingly, other institutional investors exhibit poor market-timing skills, as they strongly increased their participation in the stock market in the last quarter of 2008, and decreased their participation in the first quarter of 2009. Non-institutional investors decreased their participation in both the third quarter of 2007 and the fourth quarter of 2008. Like hedge funds, non-institutional investors substantially increased their stock market participation in the first quarter of 2009.

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

To summarize, it appears that both non-institutional investors and other non-mutual-fund institutional investors took the other side of hedge fund trades. In Section 4, we analyze further and in more depth the differences in the behavior of mutual and hedge funds.

3. Hedge Fund Trades and Financial Constraints

So far, we have documented large selling on the part of hedge funds during the financial crisis. Next, we turn to investigating the determinants of this behavior.

Based on the accounting identity that links a hedge fund's assets to its liabilities, the change in equity holdings must be matched by the change in assets under management plus the change in liabilities (including short positions) minus the change in other investments (including cash). Due to a lack of the required information, we cannot fully implement this decomposition. While TASS allows us to retrieve the flows into AUM, there is no time-series dimension for debt, as the leverage variable in TASS is a snapshot at the time of reporting. Investments in cash or assets other than U.S. equities are also unobservable. Short positions are not available at the hedge fund level. While the analysis of aggregate short interest in Section 2 revealed that hedge funds' stock selloffs happened at the same time short positions were closed, it still remains to be clarified why hedge funds deleveraged both sides of their equity portfolios in a falling market.

Our empirical analysis draws inspiration from the limits-of-arbitrage literature cited in the introduction. These theories postulate that arbitrageurs cannot exploit mispricing and monetize the illiquidity premium because their capital is cut off. Consequently, we conjecture that an important motivation behind the selloffs is financial constraints. That is, we test the hypothesis that investors and lenders forced hedge funds to liquidate equity positions by cutting back on their funding. To do so, we construct a first set of tests so that we can relate hedge fund trades to fund flows. Then, in a second set of tests, we study whether highly leveraged hedge funds are more likely to sell equities. In this case, the underlying assumption is that, all else being equal, funds with higher leverage are more likely to run into risk limits or receive margin calls that force them to deleverage. Finally, we look at which stocks were sold by hedge funds, as this can also be informative with regard to the motives behind the selloffs.

We do not neglect the possibility that hedge funds liquidated their stock positions to pursue profit opportunities in other asset classes. At first glance, this channel appears to be an alternative to the financial constraints motive mentioned above. However, to the extent that mispriced securities still existed in the equity market during the crisis (as Nagel 2011 shows), the fact that hedge funds were obliged to forego these profits to free up capital for use in other markets is itself an indirect manifestation of financial constraints.

Arbitrageurs without capital constraints should be able to take advantage of all available profit opportunities. We investigate the evidence for the asset reallocation channel in an Online Appendix; the results are summarized in Section 3.5.

3.1 Redemptions by investors

First, we investigate to what extent investor redemptions drove stock sales by hedge funds during the crisis. We compute fund flows (scaled by the lagged equity portfolio value) using TASS data, and thus we restrict the 13F dataset to the sample matched with TASS between 2004:Q1 and 2009:Q4.

Figure 3 has the time series of aggregate net flows as a fraction of AUM for all the funds in our data. A clear pattern emerges where the net flows for the hedge fund sector are negative during the selloff quarters and/or the next periods. Redemptions were extremely severe following the collapse of Lehman Brothers. In 2009:Q1, net flows reached almost -15% of AUM. The graphic impression is that outflows are a potentially important driver of the stock selloffs.

Next, we systematically investigate the relation between stock trades and fund flows in a fund-level regression setting. The dependent variable is the

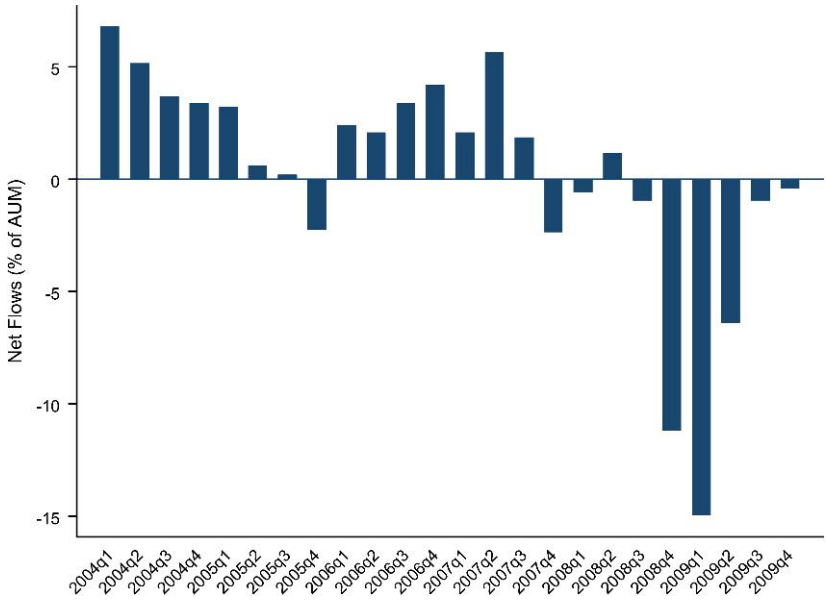

Figure 3
Time series of aggregate net flows (% of assets under management)
The figure plots the aggregate net flows for hedge funds in the intersection between 13F and TASS as a fraction of their aggregate assets under management in the previous quarter (in percent). Fund flows are computed as the quarterly change in AUM minus the dollar return on prior-quarter AUM. The series ranges from 2004:Q1 to 2009:Q4.

percentage change in fund-level equity holdings as a fraction of prior-quarter equity holdings. The explanatory variable of interest is net fund flows as a percentage of the prior-quarter AUM. Along with contemporaneous flows, we consider two quarterly lead flows, as 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 (e.g., Agarwal, Daniel, and Naik 2009).

We present the results in Table 4. Standard errors are clustered at the calendar-quarterly level. Column 1 has the baseline regression. We note that based on this sample, hedge funds reduced their equity portfolios by 11.5% per quarter on average during selloff quarters (i.e., 2007:Q3–Q4 and 2008:Q3–Q4), relative to other quarters. This result confirms, at the fund level, the aggregate result from Table 2; it also shows its statistical significance.

In Column 2 in Table 4, we introduce fund flow variables as well as interactions of the selloff quarter dummy with current and future fund flows. The regression shows that future flows are positive and statistically significant. Incidentally, the coefficients on the interactions with the selloff quarter dummy are statistically insignificant, suggesting that the impact of redemptions on changes in holdings is not stronger in the selloff quarters than it is in other quarters. This fact does not weaken our conclusion. It suggests that the response of hedge funds to investor flows is the same during both crisis and ordinary periods. Still, redemptions were stronger during the crisis quarters, causing hedge funds to reduce their equity holdings substantially. These results confirm that redemptions were a major determinant of the selloffs. Controlling for flows reduces the magnitude of the selloff quarter coefficient from –11.5% to –6.5%, a 43% decline.

One may be concerned that future fund flows is an endogenous variable in the above regressions. It could be that future fund flows depend on current performance, which in turn correlates with the dependent variable (the change in equity holdings) if, say, the current sales are dictated by current poor performance. We address this concern in two ways. First, in Table 4, Column 3, we include the contemporaneous total returns in the specification and observe that future fund flows retain their significance. Second, we replace all fund flow variables with the fitted values from a first-stage regression of fund flows in quarter $q + 1$ onto returns in quarters q, $q - 1$, and $q - 2$. In this way, we exploit the flow-performance relation without directly including future variables on the right-hand side. Appendix Table A1 has the estimates for all the specifications in this section that involve fund flows. The inference from this exercise is that predicted flows, both in isolation and interacted with the selloff quarter dummy, have strong explanatory power for the change in equity holdings that takes place during selloff quarters. The decrease in the absolute value of the selloff quarter dummy, in moving from Column 1 to Column 2 of Table A1, is of comparable magnitude to the corresponding decline in Table 4.

Table 4
Hedge fund trading and the financial constraints channel

	Dependent variable: A HF equity portfolio(%)									
	Investor redemptions			Lender pressure		All financial constraints		Sample: Long-short only		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Selloff quarter	−11.529***	−6.516	−5.297	−12.118***	−6.991	−2.653	−1.865	−7.162**	0.179	2.137
	(−4.130)	(−1.718)	(−1.246)	(−4.445)	(−1.564)	(−0.544)	(−0.352)	(−2.175)	(0.020)	(0.280)
× Fund flows		−0.198	−0.047			−0.421	−0.145		−0.500*	−0.198
		(−0.750)	(−0.167)			(−1.316)	(−0.488)		(−1.798)	(−0.623)
× lead(Fund flows)		0.100	−0.114			0.070	−0.234		0.278*	0.024
		(0.884)	(−0.821)			(0.385)	(−0.882)		(1.866)	(0.116)
× lead2(Fund flows)		0.020	−0.093			0.066	−0.070		0.007	−0.168
		(0.141)	(−0.561)			(0.493)	(−0.442)		(0.025)	(−0.584)
× Avg. leverage					−5.982**	−5.711***	−5.508***		−2.382	−2.970
					(−2.281)	(−2.903)	(−3.349)		(−0.244)	(−0.379)
× Total Returns (q)			0.673***				1.003***			1.029***
			(4.441)				(5.154)			(3.404)
Fund flows		0.160	0.170			0.193	0.197		0.341***	0.345***
		(0.874)	(0.934)			(1.461)	(1.456)		(2.961)	(2.911)
lead(Fund flows)		0.396***	0.374***			0.384**	0.377**		0.264***	0.254***
		(3.892)	(3.521)			(2.400)	(2.297)		(3.605)	(3.258)
lead2(Fund flows)		0.157*	0.150*			0.060	0.058		0.049	0.049
		(2.036)	(1.993)			(0.954)	(0.906)		(0.728)	(0.729)
Avg. leverage					4.476***	4.326***	4.333***		3.315*	3.307*
					(4.293)	(4.382)	(4.402)		(1.983)	(1.969)
Total Returns (q)			0.189				0.071			0.068
			(1.315)				(0.450)			(0.577)
Constant	12.704***	11.863***	11.338***	13.038***	9.309***	8.919***	8.718***	6.081***	2.616	2.424
	(6.487)	(5.878)	(5.604)	(6.841)	(4.267)	(4.062)	(3.822)	(4.374)	(1.126)	(1.027)
Observations	2053	2053	2053	1332	1332	1332	1332	666	666	666
Adj R^2	0.009	0.038	0.042	0.009	0.016	0.039	0.046	0.003	0.039	0.051

The table reports results from the OLS fund-level regressions in which the dependent variables are hedge fund trades as a fraction of the hedge fund equity portfolio, evaluated at prior-quarter prices. The explanatory variables include the selloff quarter dummy and the level and interactions of fund flows (current and two leads), average leverage, and the total hedge fund return in the quarter. Selloff quarters are 2007:Q3–Q4 and 2008:Q3–Q4. The sample used in Columns 8-10 is restricted to hedge funds that engage in a long-short strategy. Standard errors are clustered at the calendar quarter level. *t*-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 2004:Q1 to 2009:Q4.

In Column 3 in Table 4, we notice that the positive slope on the interaction of returns with the selloff quarter dummy is more significant than the slope on returns. This finding lends itself to an interpretation that is consistent with a tightening of financial constraints during the crisis. The negative returns earned during the selloff quarters caused a drop in AUM. In turn, a capital decrease obliged hedge funds to deleverage in order to remain within the maintenance margins for their positions. The stronger significance of the interaction likely suggests that this effect was magnified by an across-the-board increase in margin requirements, which occurred during the crisis (e.g., Brunnermeier and Pedersen 2009; Metrick and Gorton 2010).

Of particular interest are hedge funds that engage in long-short strategies. This style is the most representative, with roughly a third of AUM held by the funds in our dataset. Furthermore, their focus is entirely on the equity market. Hence, we should expect these funds to be important drivers of hedge fund stock trading in general. Explaining their motives for selloffs can also shed light on the unwinding of short positions that took place simultaneously.

3.2 Credit tightening and risk management

Next, we look for evidence that hedge funds reduced their equity positions because they were forced to do so by margin calls and/or because they ran into risk management limits. In the case of margin calls, the financial constraints are explicitly imposed by brokers (Brunnermeier and Pedersen 2009). In contrast, risk management limits are put into place by the fund itself in order to avoid capital calls by its investors or lenders (e.g., Vayanos 2004). In either case, hedge funds that are more leveraged are expected to be exposed to greater pressure to liquidate their positions during a crisis.

Our test focuses on the prediction that stock selloffs during the crisis were higher for hedge funds with higher leverage. We employ the same fund-level regression setting used in the previous subsection. In Column 5 of Table 4, we regress the fraction of the equity portfolio traded by hedge funds on the selloff quarter indicator interacted with hedge funds' average leverage. 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 selloff quarters. Average leverage is measured as debt over investor equity. The size of the coefficient is –6.0% and should be multiplied by the leverage in order to get the economic effect. During selloff quarters, a 2:1 leveraged hedge fund sells 3.0% more of its equity portfolio than does an unleveraged fund.[21] By comparing the slope on the selloff quarter dummy in Column 5 (–7.0%) with the same coefficient in the base specification in the sample of funds with available leverage (Column 4) (–12.1%), we conclude that leverage explains about 42% of the sales during the selloff quarters.

[21] 2 * (–5.982% + 4.476%) = –3.012%.

We also assess the total effect of financial constraints on hedge fund equity trading (that is, on redemptions and leverage combined). In Table 4, Column 6, we regress the changes in equity holdings on the crisis indicator interacted with both the fund flow variables and the average leverage. The main effects are also included. By comparing the coefficient on the selloff quarter dummy to the coefficient in Column 4, we conclude that financial constraints account for about 78%[22] of the size of the decline in stock holdings by hedge funds during the selloff quarters.

3.3 Long-short hedge funds

We limit the sample to hedge funds that have assets in the long-short strategy and reestimate the main regressions (Columns 8–10). The results show that long-short hedge funds reduced their holdings during the selloff quarters by about 7.2% on average (Column 8). This smaller magnitude relative to Column 1 should not lead one to think that the absolute amount of long-short funds' stock selloffs is smaller. The average size of their equity portfolios is around $946M, which exceeds the average size for the entire sample of hedge funds, roughly $646M. Hence, in absolute terms, the stock sale by the average fund in the long-short style is of similar magnitude to the sale of the average fund in the overall sample. Moving to Columns 9 and 10, we observe that the decline in equity holdings is fully explained by redemptions. We find this evidence consistent with the idea that long-short funds unwound their positions to respond to the redemptions. One can also indirectly infer that the short positions were closed because the margins could not be maintained when capital was reduced. Finally, we notice that while contemporaneous redemptions have low explanatory power for the whole sample of funds, they have a significant explanatory power for long-short fund trades. We conjecture that these equity-focused funds provide more liquidity to their investors in the form of shorter redemption notice periods. The average redemption notice periods for long-short fund and non-long-short funds are 43.2 and 52.7 days, respectively. A test for the equality of these means rejects the null with a *t*-statistic of 11.3. The data therefore seem to confirm the conjecture that investors in long-short funds were able to withdraw their capital at an earlier date than was the case for investors in other strategies. This fact can explain why contemporaneous flows are a significant determinant of the trades of long-short funds during the selloff quarters.

3.4 Which stocks were sold?

Analyzing the characteristics of the stocks traded by hedge funds can help reveal the motives of the trades. Among the stock characteristics that we study, we focus on total volatility (computed using the 24 monthly returns up to the

[22] 1 – (–2.653% / –12.118%) = 78.135%.

beginning of the quarter) in order to identify the risk management motive. Then, we look at liquidity as measured by the price impact ratio of Amihud (2002).[23] In this case, we seek to contribute to the debate started by Scholes's (2000) on the liquidation problem faced by an investor with both liquid and illiquid securities in his portfolio. Scholes's observation is that investors sell the most liquid securities in their portfolios in order to minimize price impact. Brown, Carlin, and Lobo (2010) solve the optimal liquidation problem in a dynamic framework. They show that investors may decide to postpone selling their most liquid securities if they expect that their liquidity needs will be more severe in later periods. Next, we consider market capitalization (at the beginning of the quarter) as a proxy for both risk and liquidity, and as a signal of potential underpricing (Fama and French 1992). Also, we study book-to-market (measured using the stock price and the latest book value at the beginning of the quarter) as a signal of potential undervaluation (Fama and French 1992). Finally, we focus on past-six-month returns at the beginning of the quarter to capture momentum strategies (Jegadeesh and Titman 1993). For each of these characteristics, we define a dummy variable that equals one if the stock is in the top half of the distribution in a given quarter.

For each stock, we compute the quarterly change in hedge fund holdings as the total number of shares held by hedge funds at the end of the quarter minus the total number of shares held by hedge funds at the end of the previous quarter scaled by the total number of shares outstanding at the beginning of the quarter.[24] This is our dependent variable in Columns 1 and 2 of Table 5; the latter specification also includes time fixed effects. Our specifications include the level of hedge fund ownership in the prior quarter to account for the fact that the amounts traded are also dependent on the amount of ownership at the beginning of the period. Standard errors are clustered at the quarterly level. The coefficient of interest is the interaction between the stock characteristic dummies and the selloff quarter dummy.

We infer that hedge funds sold more high- than low-volatility stocks during the selloff quarters. This is consistent with the prediction of limits-to-arbitrage theories, that speculators are forced to reduce exposure to risky assets in bad times. For example, Brunnermeier and Pedersen (2009) posit that high-volatility assets require higher margins and thus may get disposed of first. Furthermore, hedge funds may close high-volatility positions in an attempt to reduce the overall portfolio volatility due to risk management considerations (e.g., if they are constrained by VaR limits, as in Vayanos 2004).

Next, it appears that hedge funds tended to hold on to illiquid stocks and to sell the ones with a low price impact first. This evidence confirms the static liquidation behavior described by Scholes's (2000) and is consistent with the

[23] Amihud (2002) computes a stock-level illiquidity measure as the average of the absolute value of daily returns over the daily dollar volume.

[24] The number of shares is adjusted for stock splits.

Table 5
Hedge fund trading and stock characteristics

	Δ HF holdings (%)		ΔShort interest ratio (%)	
Dependent variable:	(1)	(2)	(3)	(4)
Selloff quarter	−0.682**		−1.039*	
	(−2.723)		(−2.052)	
× High volatility indicator	−0.579***	−0.577***	−0.599**	−0.587***
	(−3.721)	(−3.702)	(−2.804)	(−2.832)
× High Amihud ratio indicator	0.844***	0.832***	1.066**	1.033**
	(3.590)	(3.534)	(2.152)	(2.124)
× High size indicator	−0.125	−0.136	0.413*	0.383*
	(−1.149)	(−1.314)	(1.964)	(1.777)
× High book-to-market indicator	−0.195***	−0.189***	0.020	0.053
	(−4.891)	(−4.923)	(0.214)	(0.678)
× High past 6m ret indicator	−0.059*	−0.045	−0.198	−0.086
	(−1.950)	(−0.754)	(−1.274)	(−0.793)
High volatility indicator	0.332***	0.334***	0.265***	0.272***
	(7.405)	(7.437)	(3.378)	(3.568)
High Amihud ratio indicator	−0.250***	−0.254***	−0.290*	−0.306**
	(−3.660)	(−3.741)	(−1.978)	(−2.106)
High size indicator	−0.005	−0.008	0.428***	0.431***
	(−0.084)	(−0.131)	(5.147)	(5.210)
High book-to-market indicator	−0.048	−0.049	−0.107***	−0.111***
	(−1.545)	(−1.628)	(−3.427)	(−3.648)
High past 6m ret indicator	0.015	0.019	−0.024	−0.021
	(0.629)	(0.765)	(−0.544)	(−0.526)
Holdings (q–1)	−0.045***	−0.046***	−0.094***	−0.098***
	(−6.118)	(−6.244)	(−3.191)	(−3.472)
Constant	0.553***		0.435**	
	(6.539)		(2.564)	
Quarter FE	No	Yes	No	Yes
Observations	94614	94614	94357	94357
Adj R^2	0.028	0.038	0.069	0.108

The table reports results from stock-level OLS regressions. In Columns 1 and 2, the dependent variable is the change in hedge fund holdings as a percentage of shares outstanding. In Columns 3 and 4, the dependent variable is the change in short interest as a percentage of shares outstanding. The explanatory variables include a set of indicator variables for when stock characteristics are above the median in the quarter, the selloff quarter dummy, the interaction between the characteristic dummy variables and the selloff quarter dummy, and hedge fund ownership in the previous quarter. The stock characteristics (measured at the beginning of the quarter) are total volatility, the Amihud (2002) ratio, market capitalization (size), the book-to-market ratio, and the past six-month returns. Selloff quarters are 2007Q3–Q4 and 2008Q3–Q4. Standard errors are clustered at the calendar quarter level. *t*-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 2004Q1 to 2009Q4.

assumption of myopic investors in the dynamic model of Brown, Carlin, and Lobo (2010). Similar to our findings, Jotikasthira, Lundblad, and Ramadorai (2009) document that during fire sales, mutual and hedge funds tend to reduce price impact, and Manconi, Massa, and Yasuda (2010) show that during the recent crisis, mutual funds decided to sell liquid securities first.

Controlling for volatility and liquidity, there is no significant action on the size dimension. Instead, it appears that hedge funds dropped high book-to-market stocks during the selloff quarters. This is also indicative of fire sales, as these stocks were potentially more underpriced and in normal times hedge funds would have held on to them. Finally, there is some marginally significant evidence of the unwinding of momentum strategies during these quarters.

To proxy for the unobservable evolution in hedge fund short positions, in Columns 3 and 4 in Table 5 we study the change in stock-level short interest as the percentage of shares outstanding. The specifications resemble those in the previous two columns. To a large extent, the evidence mirrors the results from the long side of the hedge fund portfolio. Short sellers were more likely to close positions in high-volatility stocks, providing evidence of volatility reduction that is symmetric to a similar reduction on the long side. Indeed, a hedge fund can reduce its VaR by limiting exposure to volatile stocks on the long as well as the short sides of its portfolio. Also, this finding suggests that the result of the sales of high-volatility stocks is not due to the fact that hedge funds are bearish on this asset class. A negative outlook on these stocks would not explain why they also reduce the short interest. Similar to the long side, the evidence that short interest decreased more for liquid stocks suggests that, during this deleveraging process, hedge funds were trying to contain the price impact.

Overall, the analysis of stock characteristics confirms the financial constraints explanation as a prominent determinant of crisis selloffs. Forced deleveraging, which results from redemptions, margin calls, and risk management limits, is likely behind the liquidation of high-volatility stocks and the rush to sell off the most liquid stocks in the portfolio. It can also account for the unwinding of value and momentum strategies, which hedge funds typically pursue.

To summarize the evidence in Section 3, we find strong support for the hypothesis that sales of stocks by hedge funds during the financial crisis were motivated by financial constraints. These can take the form of redemptions, margin calls, and risk limits. The combined effect of these forces appears to be the main driver behind hedge fund stock sales during the selloff quarters. The financial constraints channel is also consistent with the parallel behavior of long and short equity positions. A decrease in capital, along with tighter limits on the amount of leverage, did not allow hedge funds to continue supporting both the long and the short sides of their portfolios.

3.5 Asset reallocation

Some hedge funds may have sold during the crisis because they found superior profit opportunities in other markets. As stated above, this fact can be interpreted as a reflection of the financial constraints explanation. In the absence of financial constraints, hedge funds should be able to invest in other markets without liquidating their positions in the equity market, if mispricing also persists in the equity market, as the depressed valuations likely suggest. To explore the asset reallocation channel further, we conduct a series of tests that are described in detail in the Online Appendix.

Here, we summarize the main results of this analysis. We classify hedge funds according to their familiarity with assets other than equity. Specifically,

we conjecture that hedge funds whose stated strategies are not equity-focused are more likely to shift investments from the equity market to other markets due to their better knowledge of the other assets. Consistent with our expectations, we find that these non-equity-focused hedge funds are more likely to sell during the crisis. In conjunction with the financial constraints motive (discussed in Sections 3.1. and 3.2), the asset reallocation channel helps explain hedge funds' entire selling pattern during the crisis.

Moreover, by looking at hedge fund return correlations with asset indexes, we find that hedge funds that exited the stock market invested mainly in government and corporate bonds. The increased correlation with government bonds suggests a flight to quality, while the investment in corporate bonds may be consistent with the idea that hedge funds chased profit opportunities in a depressed market.

Finally, we show that hedge funds that exited the stock market during the selloff quarters exhibited significantly higher returns than they did in the quarters that followed, supporting the idea that they sold stocks in order to invest in profitable opportunities elsewhere.

4. What Differentiates Hedge Funds from Mutual Funds?

Given the intense selling by hedge funds during the financial crisis, one wonders what differentiates hedge funds from other types of institutional investors that did not sell stocks as significantly during this period (Table 3, Panel A). The case of mutual funds is especially intriguing since mutual funds do not have liquidity restrictions and are thus potentially more subject to investor redemptions than are hedge funds. Nevertheless, as observed in Table 3, Panel A, mutual funds did not engage in major selloffs during the crisis.

There are two key differences between hedge funds and mutual funds that can explain their respective selling behaviors in conjunction with financial constraints. First, in contrast to mutual funds, hedge funds' positions are often based on leverage. Hence, a decline in the asset value may trigger liquidation if margin requirements are not satisfied. We provide evidence for such a mechanism in Section 3.2. As shown, leverage effects account for about 42% of the selling activity by hedge funds during the crisis. Second, the investor base for hedge funds is different from that of mutual funds. Specifically, mutual fund clients are primarily retail investors, while investors in hedge funds are wealthy individuals or institutions (e.g., funds-of-funds, endowments, pension funds). Thus, hedge fund investors might have different redemption patterns than do mutual fund investors. For example, hedge fund investors may be more financially sophisticated and may therefore react more quickly to past returns. Or, investors in hedge funds may be subject to institutional or regulatory constraints that force them to liquidate losing investments.

Table 6 provides descriptive evidence on the different roles that redemptions played in these two types of institutions during the crisis. We compare the hedge funds from our preceding analysis with all the mutual funds from the CRSP database that focus on the U.S. stock market. Column 1 reports net flows as a fraction of AUM in the previous quarter. By comparing Panels A and B, we notice that during the crisis period, hedge funds suffered from significant redemptions, whereas mutual funds were less exposed to outflows.

In Column 2 in Table 6, we have net trades in stocks as a fraction of the value of the equity portfolio in the previous quarter (for hedge funds, this is the same information reported in Table 2, Column 1). Hedge funds traded much more actively than did mutual funds. For example, while mutual funds also dumped

Table 6
Quarterly summary statistics for hedge funds and mutual funds

Panel A: Summary statistics for hedge funds

		Hedge hinds		
		Flows/AUM (%)	Trades/Total equity portfolio (%)	Quarterly returns (%)
		(1)	(2)	(3)
Pre-crisis	2004Q1-2007Q2	2.87	6.13	2.57
Crisis	2007Q3-2009Q1	−3.86	−3.06	−1.82
Post-crisis	2009Q2-2009Q4	−2.58	5.60	5.37
	2007Q3	1.83	−9.87	−0.88
	2007Q4	−2.34	−2.74	1.64
	2008Q1	−0.56	4.72	−1.91
	2008Q2	1.11	3.57	2.85
	2008Q3	−0.94	−16.70	−7.69
	2008Q4	−11.19	−14.26	−7.36
	2009Q1	−14.93	13.88	0.59

Panel B: Summary statistics for mutual funds

		Equity Mutual funds		
		Flows/AUM (%)	Trades/Total equity portfolio (%)	Quarterly returns (%)
		(1)	(2)	(3)
Pre-crisis	2004Q1-2007Q2	1.17	1.61	2.82
Crisis	2007Q3-2009Q1	0.12	−0.18	−7.22
Post-crisis	2009Q2-2009Q4	1.63	0.55	11.82
	2007Q3	0.79	0.83	1.86
	2007Q4	0.46	1.36	−2.39
	2008Q1	0.08	−0.04	−8.90
	2008Q2	0.79	−4.89	0.15
	2008Q3	0.59	−0.12	−11.12
	2008Q4	−0.92	−0.24	−22.13
	2009Q1	−0.92	1.87	−7.97

The table reports summary statistics for hedge funds (Panel A) and U.S. equity-focused mutual funds (Panel B) during selected subperiods. Column 1 presents aggregate flows scaled by aggregate assets under management in the previous quarter (AUM). Column 2 shows the aggregate net trades scaled by the total size of the equity portfolio in the previous quarter. Column 3 presents the average quarterly returns earned by funds during each subperiod.

stocks in the last two quarters of 2008, their trades were an order of magnitude smaller than the selloffs by hedge funds. This finding is consistent with the evidence on flows from Column 1. Also, mutual funds are often committed to track a benchmark, which means that they do not have the same discretion hedge funds do in revising their asset allocation; this commitment obliged them to remain invested in equity during the crisis.

Finally, in Column 3 in Table 6, we have quarterly returns for the two types of institutions. Hedge funds fared much better than mutual funds during the crisis period. We have also restricted the analysis to hedge funds with an explicit focus on equity (that is, with assets in long-short, short bias, and market-neutral strategies that exceed 50% of total AUM). The returns for this restricted set of hedge funds are similar to those for the whole sample and are much better than the returns for equity mutual funds. Overall, the redemptions that hedge funds suffered during the crisis do not seem to have put them at a disadvantage relative to mutual funds in terms of performance.

In the next subsections, we investigate more systematically the determinants of the different trading behaviors of hedge and mutual funds during the crisis.

4.1 Flow-performance sensitivity

In order to provide more systematic evidence about the different behavior of investors in mutual and hedge funds, we estimate the flow-performance relations for both types of institutions. Several studies analyze how mutual-fund investors react to past performance (e.g., Chevalier and Ellison 1997; Sirri and Tufano 1998). One finding of this literature is that mutual fund flows have a convex relation with past performance: Mutual funds receive large inflows following a good past performance, while suffering smaller outflows following a poor past performance. For hedge funds, in contrast, the evidence is mixed. While Agarwal, Daniel, and Naik (2004) find a convex relation for individual funds, Goetzmann, Ingersoll, and Ross (2003) find a concave relation. More recently, Baquero and Verbeek (2009) and Li, Zhang, and Zhao (2011) find the flow-performance relation to be linear. Ding et al. (2009) seem to reconcile the hedge fund evidence, as they suggest that the relation is convex in the absence of share restrictions, but that it becomes concave for hedge funds that limit the liquidity of their shares. The explanation is that investors in these funds are more reactive to poor performance, as they fear a future restriction on redemptions in the case of prolonged poor performance.

For our purposes, the interest lies primarily in the difference in the sensitivity of investors to poor performance between mutual and hedge funds. A heightened reaction of hedge fund investors would contribute to an explanation of the larger redemptions hedge funds suffered during the crisis. To test the conjecture that the response of investors is different across the two types of investment vehicles in our sample period, we construct a pooled dataset that contains quarterly observations of returns and flows for mutual and hedge funds. For each observation, we require funds to have quarter

q + 1 flows (expressed as a percentage of AUM at quarter q) as well as contemporaneous quarterly performance. For each fund in the database, we compute the percentile rank performance relative to a benchmark group in the same quarter.[25] Since we also examine hedge fund performance ranking within investment style, this analysis is performed at the hedge fund level rather than at the hedge fund-management company level. Each fund has a ranking between 0 and 1 (*FRank*). We then follow the piecewise linear regression approach of Ding et al. (2009), in which they explore the flow-performance sensitivity for three regions of past returns (funds with low, mid-range, and high past returns). We compute the following variables that split the rank variable into three ranges:

$$\begin{aligned} TRank1_{i,t} &= \min\left(\frac{1}{3},\ FRank_{i,t}\right) \\ TRank2_{i,t} &= \min\left(\frac{1}{3},\ FRank_{i,t} - TRank1_{i,t}\right) \\ TRank3_{i,t} &= \min\left(\frac{1}{3},\ FRank_{i,t} - TRank1_{i,t} - TRank2_{i,t}\right). \end{aligned} \tag{1}$$

In Table 7, we regress next-quarter flows on the current performance rank variables. The coefficients on the variables *TRank1*, *TRank2*, and *TRank3* reflect the sensitivity of flows to mutual funds' past performance. Consistent with the literature, the table shows that the pattern of the flow-performance relationship is convex for mutual funds: The coefficient on *TRank1* (poor past performance) is 7.2% in Column 1, while the coefficient on *TRank3* is 53.8% (good past performance).

Table 7 allows us to contrast the flow-performance relation for hedge funds with that of mutual funds. The interaction of *TRank* with the hedge fund indicator reflects the additional sensitivity for hedge funds, on top of the coefficient for mutual funds. Column 1 shows that the sensitivity for poor-performing hedge funds is nearly three times higher: 20.5% for poor-performing hedge funds, relative to 7.2% for poor-performing mutual funds. The results for the downside performance sensitivity are generally robust to within-style ranking (Columns 4–6), and also for the subsample of hedge funds that specialize in equity investing (Columns 7–9). These findings are consistent with Li, Zhang, and Zhao (2011), who find that hedge fund investors have an almost linear response function to past performance. The finding that the additional sensitivity to hedge funds' poor past performance is only marginally significant during the crisis periods (Columns 3, 6, and 9) is consistent with the fact that, at that time, many hedge funds raised their gates and limited their

[25] Mutual funds' performance is compared to the universe of equity mutual funds in our database in the same quarter. For hedge funds, we offer two benchmark groups: either the universe of hedge funds in the same quarter or hedge funds of the same investment style in the same quarter. Table 7 presents results for both groups.

Table 7
Flow-performance relation of hedge funds and mutual funds

	Dependent variable: Flows (q+1) / AUM(q)								
Ranking / sample:	Absolute ranking			Within-style ranking			Only equity HFs and MFs		
Sample period:	All qtrs	Non-Crisis	Crisis	All qtrs	Non-Crisis	Crisis	All qtrs	Non-Crisis	Crisis
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
TRank1	0.072**	0.116**	−0.036	0.094***	0.129***	0.010	0.079**	0.124**	−0.029
	(2.067)	(2.715)	(−0.929)	(3.146)	(3.353)	(0.393)	(2.241)	(2.852)	(−0.698)
×I(Hedge fund)	0.133***	0.147***	0.111*	0.120***	0.123**	0.115**	0.124**	0.117**	0.122
	(3.601)	(3.062)	(1.970)	(3.425)	(2.618)	(2.542)	(2.763)	(2.165)	(1.336)
TRank2	−0.049**	−0.091***	0.057	−0.050**	−0.093***	0.056	−0.047*	−0.089***	0.056
	(−2.061)	(−3.661)	(1.941)	(−2.093)	(−3.723)	(1.865)	(−2.026)	(−3.572)	(1.922)
× I(Hedge fund)	0.099***	0.118***	0.038	0.117***	0.154***	0.020	0.059	0.081**	0.015
	(3.831)	(3.691)	(0.967)	(3.771)	(4.004)	(0.649)	(1.525)	(2.456)	(0.148)
TRank3	0.538***	0.593***	0.402***	0.523***	0.584***	0.372***	0.527***	0.581***	0.392***
	(11.253)	(11.001)	(4.832)	(10.851)	(10.716)	(4.783)	(11.134)	(10.889)	(4.766)
× I(Hedge fund)	−0.096*	−0.159**	0.060	−0.124**	−0.192***	0.042	−0.076	−0.155**	0.117
	(−1.744)	(−2.721)	(0.562)	(−2.137)	(−3.077)	(0.402)	(−1.085)	(−2.124)	(0.856)
I(Hedge fund)	−0.118***	−0.108***	−0.144***	−0.116***	−0.105***	−0.140***	−0.123***	−0.107***	−0.161***
	(−11.618)	(−8.639)	(−10.442)	(−12.596)	(−9.377)	(−12.188)	(−10.525)	(−7.931)	(−9.992)
log(AUM)	−0.034***	−0.036***	−0.032***	−0.035***	−0.036***	−0.032***	−0.038***	−0.039***	−0.036***
	(−21.047)	(−16.146)	(−15.410)	(−21.043)	(−16.188)	(−15.181)	(−19.720)	(−15.805)	(−11.994)
Calendar Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	204240	145262	58978	204240	145262	58978	132013	94467	37546
Adj R^2	0.082	0.080	0.084	0.080	0.078	0.081	0.088	0.089	0.086

The table reports results from fund-level OLS regressions. The sample contains quarterly observations of hedge funds and U.S. equity-focused mutual funds. The dependent variable is investor flows scaled by assets under management. *TRank1* is a variable that contains the ranking of the fund relative to a benchmark group (ranking between 0 and 1) if the ranking is in the bottom tercile, and zero otherwise. *TRank2* is a variable that contains the ranking of the fund relative to a benchmark group (ranking between 0 and 1) if the ranking is in the middle tercile, and zero otherwise. *TRank3* is a variable that contains the ranking of the fund relative to a benchmark group (ranking between 0 and 1) if the ranking is in the top tercile, and zero otherwise. *I(Hedge fund)* indicates whether the observation is a hedge fund. All mutual funds are ranked within the universe of mutual funds. *Absolute ranking* is a ranking of hedge funds within the contemporaneous universe of hedge funds. *Within-style ranking* is a ranking of hedge funds within the contemporaneous universe of self-reported style hedge funds. Crisis quarters are 2007:Q3 to 2009:Q1. Standard errors are clustered at the calendar quarter level. *t*-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 2004:Q1 to 2009:Q4.

investors' ability to withdraw funds. This issue is further discussed in relation to Table 7.

One potential concern about this analysis is that the flows into mutual and hedge funds are differently sensitive to performance if the absolute performance of these two types of institutions differs substantially. Panel E of Table 1 compares the return distributions of mutual and hedge funds in the three terciles of performance that are used to construct *TRank*. Across the terciles, the returns behave very similarly, which attenuates the initial concern. Still, in the first tercile, hedge funds seem to have more extreme negative returns than do mutual funds. To rule out the possibility that some outliers are driving the flow-performance regressions, we have dropped observations below the 5th and above the 95th percentiles of the return distribution for each institution type. The significance of the estimates of the flow-performance regressions is not affected (results available upon request).

4.2 Determinants of flow-performance sensitivity

The results so far suggest that hedge fund investors are more sensitive to poor past performance than are investors of mutual funds. We want to explore the sources of hedge fund investors' higher sensitivity. First, drawing on prior literature, we conjecture that a difference in share illiquidity between hedge funds and mutual funds causes hedge fund investors to react more aggressively to poor past performance. Second, we investigate whether the prevalence of institutional clients in hedge funds makes them more subject to outflows and forced selling.

4.2.1 Restrictions on capital withdrawals. We explore the role of share restrictions by testing whether tighter liquidity restrictions are associated with stronger flow-performance sensitivity. In Table 8, we follow Ding et al. (2009) and repeat the flow-performance regressions while adding interactions with an indicator of hedge fund illiquidity. Hedge funds are considered illiquid if they have a lockup period or if their redemption notice period is longer than 30 days.

Interestingly, the sensitivity of flows to past performance is different in normal times from what it is in crisis periods. In accordance with the results of Ding et al. (2009), we find that during non-crisis periods, investors in hedge funds with liquidity constraints exhibit a relation between flows and performance that is three times as strong as it is for mutual fund investors.[26] On the other hand, during crisis periods, hedge funds with liquidity constraints are not different from other hedge funds. This latter piece of evidence is consistent with the view that tighter restrictions on withdrawals are implemented in bad times, so that sensitivity to poor performance is necessarily attenuated. The

[26] To see this result, add the coefficients on TRank1 and on the interactions with the indicators for hedge funds and constrained hedge funds.

Table 8
Flow-performance relation of hedge funds and mutual funds

	Dependent variable: Flows (q+1) / AUM(q)								
Ranking / sample:	Absolute ranking			Within-style ranking			Only equity HFs and MFs		
Sample period:	All qtrs	Non-Crisis	Crisis	All qtrs	Non-Crisis	Crisis	All qtrs	Non-Crisis	Crisis
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
TRank1	0.072**	0.117**	−0.035	0.095***	0.130***	0.011	0.080**	0.124**	−0.029
	(2.077)	(2.720)	(−0.910)	(3.155)	(3.358)	(0.406)	(2.242)	(2.854)	(−0.699)
× I(Hedge fund)	0.091**	0.091*	0.100	0.086**	0.070	0.123*	0.143**	0.111	0.193
	(2.264)	(1.776)	(1.420)	(2.175)	(1.363)	(2.219)	(2.572)	(1.734)	(1.514)
× I(HF with constraints)	0.070**	0.100**	0.009	0.062**	0.101***	−0.020	−0.028	0.017	−0.129
	(2.128)	(2.406)	(0.189)	(2.162)	(2.987)	(−0.435)	(−0.486)	(0.268)	(−0.962)
TRank2	−0.049*	−0.091***	0.057	−0.050**	−0.093***	0.056	−0.047*	−0.089***	0.056
	(−2.057)	(−3.656)	(1.940)	(−2.091)	(−3.719)	(1.864)	(−2.026)	(−3.571)	(1.922)
× I(Hedge fund)	0.133***	0.175***	0.019	0.167***	0.230***	0.015	0.105*	0.160***	−0.009
	(3.440)	(3.678)	(0.484)	(3.845)	(4.430)	(0.546)	(1.942)	(3.068)	(−0.071)
× I(HF with constraints)	−0.065**	−0.110**	0.033*	−0.099***	−0.151***	0.010	−0.097*	−0.161**	0.045
	(−2.066)	(−2.792)	(2.318)	(−3.190)	(−4.352)	(0.255)	(−1.732)	(−2.378)	(0.635)
TRank3	0.538***	0.593***	0.401***	0.522***	0.583***	0.371***	0.527***	0.581***	0.392***
	(11.234)	(10.999)	(4.813)	(10.835)	(10.711)	(4.765)	(11.139)	(10.888)	(4.767)
× I(Hedge fund)	−0.118*	−0.202**	0.094	−0.155**	−0.247***	0.071	−0.057	−0.152*	0.183
	(−1.759)	(−2.833)	(0.754)	(−2.327)	(−3.699)	(0.567)	(−0.701)	(−1.752)	(1.183)
× I(HF with constraints)	0.050	0.084*	−0.044	0.060	0.104**	−0.053	−0.023	0.018	−0.134
	(1.336)	(1.884)	(−0.661)	(1.596)	(2.579)	(−0.766)	(−0.435)	(0.335)	(−0.902)

(*continued*)

Table 8
Continued

	Dependent variable: Flows (q+1) / AUM(q)								
Ranking / sample:	Absolute ranking			Within-style ranking			Only equity HFs and MFs		
Sample period:	All qtrs	Non-Crisis	Crisis	All qtrs	Non-Crisis	Crisis	All qtrs	Non-Crisis	Crisis
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
I(Hedge fund)	−0.121***	−0.108***	−0.155***	−0.122***	−0.108***	−0.155***	−0.134***	−0.113***	−0.183***
	(−10.947)	(−8.714)	(−7.784)	(−12.792)	(−9.854)	(−12.899)	(−9.543)	(−7.683)	(−7.154)
I(HF with constraints)	0.008	0.002	0.022	0.013	0.006	0.027	0.019*	0.010	0.041
	(0.862)	(0.162)	(1.029)	(1.603)	(0.724)	(1.634)	(1.874)	(0.980)	(1.575)
log(AUM)	−0.035***	−0.036***	−0.032***	−0.035***	−0.036***	−0.032***	−0.038***	−0.039***	−0.036***
	(−21.047)	(−16.103)	(−15.651)	(−21.058)	(−16.161)	(−15.431)	(−19.704)	(−15.815)	(−11.990)
Calendar Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	204240	145262	58978	204240	145262	58978	132013	94467	37546
Adj R^2	0.082	0.080	0.085	0.080	0.079	0.081	0.088	0.089	0.086

The table reports results from fund-level OLS regressions. The sample contains quarterly observations of hedge funds and U.S. equity-focused mutual funds. The dependent variable is investor flows scaled by assets under management. *TRank1* is a variable that contains the ranking of the fund relative to a benchmark group (ranking between 0 and 1) if the ranking is in the bottom tercile, and zero otherwise. *TRank2* is a variable that contains the ranking of the fund relative to a benchmark group (ranking between 0 and 1) if the ranking is in the middle tercile, and zero otherwise. *TRank3* is a variable that contains the ranking of the fund relative to a benchmark group (ranking between 0 and 1) if the ranking is in the top tercile, and zero otherwise. *I(Hedge fund)* indicates whether the observation is a hedge fund. *I(HF with constraints)* indicates whether the observation is an illiquid hedge fund, i.e., it has a redemption notice longer than 30 days or a long lockup period in place. All mutual funds are ranked within the universe of mutual funds. *Absolute ranking* is a ranking of hedge funds within the contemporaneous universe of hedge funds. *Within-style ranking* is a ranking of hedge funds within the contemporaneous universe of self-reported style hedge funds. Crisis quarters are 2007:Q3 to 2009:Q1. Standard errors are clustered at the calendar-quarterly level. *t*-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 2004:Q1 to 2009:Q4.

financial press is full of examples of hedge funds that raised the gates during the recent crisis and prevented investors from withdrawing their money.[27]

Overall, the evidence is consistent with liquidity constraints making investors more sensitive to bad news during normal periods, potentially because they try to preempt further restrictions on their invested capital.

4.2.2 Composition of investor base. The composition of the investor base might be another determinant of flow-performance sensitivity. For example, there is evidence that the retail investors of mutual funds, who often invest through their pension plans, tend to be fairly insensitive to poor performance. As for institutional clients, one view is that they are more reactive to past and current events. This will be the case if the managers in charge of asset allocation in the institutional client are periodically evaluated based on the performance of their investments. Also, internal risk management systems or the funding requirements of institutional clients may force a periodic revision of the asset allocation. On the other hand, institutional decision processes may be lengthy, while individuals can enact their decisions more nimbly. Which effect prevails is ultimately an empirical question.

We want to study whether the different compositions of the client bases for mutual and hedge funds can account for the different patterns of outflows and sales during the crisis. Mutual-fund investors are primarily individuals, that is, there is no significant heterogeneity in their client base. Therefore, we implicitly assume that individual investors would react similarly in mutual funds and hedge funds, and focus on hedge funds, which have a more varied client base. Then, we test whether hedge funds with more institutional clients were subject to greater redemptions and consequently sold more stocks during the crisis.

We access the ADV filings, in which management companies report a rough breakdown of the composition of their investors, and hand-match them to hedge funds' 13F filings.[28] Because ADV filings became mandatory again in 2009, we impute the identity of hedge fund investors retroactively. This retroactive imputation may result in a survival bias where the ownership structure of hedge funds that ceased to operate before 2009 cannot be traced. The results should therefore be interpreted with this caveat in mind.

Our regressions test whether a high fraction of institutional investors is correlated with flows and with higher sales of stocks during the crisis. We create an institutional ownership variable as the average ownership by institutions (banks, mutual funds, pension funds, other pooled investment vehicles,

[27] See, e.g., http://www.bloomberg.com/apps/news?pid=newsarchive&sid=aaiL4CVMbE7s&refer=home.

[28] Investor categories include individuals, high-net-worth individuals, banks, mutual funds, pension funds, pooled investment vehicles, endowments, corporations, the government, and other. Ownership fractions are broken into categories (e.g., up to 10%, between 10% and 20%, etc.). For calculating institutional ownership, we compute the midpoint for each relevant category and take the average.

endowments, corporations, the government, and other institutions) for a given fund. This variable averages 10.6% across funds (see Table 1, Panel F).

In Table 9, Column 1, we regress the change in hedge fund equity holdings on a crisis dummy interacted with institutional ownership. Here, the crisis period is defined as the quarters between 2007:Q3 and 2009:Q1. The results show that during the crisis, hedge funds with a high concentration of institutional investors experienced lower-than-average flows. In terms of magnitude, funds with a one-standard-deviation-higher institutional ownership (2.4%, from Table 1, Panel F) sold roughly 3.8% ($= -1.6 \times 2.4$) more of their equity portfolios during the crisis. In Column 2, we test whether the effect survives once we control for share restrictions, as we have shown above that these characteristics are also important determinants of investors' redemptions. It turns out that the effect of institutional ownership is even stronger in this specification. In Columns 3 and 4, we give a more restrictive definition of the crisis period and focus on the four selloff quarters (Q3 and Q4 of 2007 and 2008). The effect of institutional ownership retains its significance after controlling for share restrictions.

In the second part of Table 9 (Columns 5–8), the dependent variable is quarter-ahead flows. The goal is to check whether redemptions were more intense for hedge funds with more institutions in their client base. The lead in the dependent variable is motivated by the evidence in Table 4 that sales are related to next-quarter flows. The right-hand-side variables mirror those in the first part of the table. When focusing on the entire crisis period (2007:Q3–2009:Q1), we find that institutional ownership is a significant determinant of outflows during the crisis. For example, in Column 6, a one-standard-deviation increase in average institutional ownership is related to 6% more outflows (as a percentage of AUM) in the next quarter. When focusing on the restrictive definition of crisis period (Columns 7 and 8), we find that the quarter-ahead flows were unconditionally negative (first row) and that institutional ownership did involve additional redemptions, albeit not at a statistically significant level (Column 8).

To summarize, our evidence suggests that hedge funds exhibited strong sell-offs during the financial crisis because of two channels. Hedge fund investors that have liquidity provisions respond more strongly to past poor performance, potentially in anticipation of further restrictions to share liquidity. In addition, our results show that hedge funds with a high concentration of institutional investors (as opposed to individuals) exhibit both stronger redemptions and more intense selling during the crisis.

Our findings are related to previous studies. Ding et al. (2009) find that investors in illiquid hedge funds exhibit a stronger sensitivity of flows to past performance. Their motivation for this finding is based on investors' concern that hedge funds will raise the gates, and therefore the investors react aggressively to bad news. Wermers (2010) finds that during the financial turmoil at the end of 2008, institutional investors front-ran retail investors by

Table 9
The effect of hedge fund institutional ownership on trades and flows

	A HF equity portfolio (%)				Flows (q+l)/AUM(q)			
I(Crisis) defined as:	2007Q3 to 2009Q1		Selloff Quarters		2007Q3 to 2009Ql		Selloff Quarters	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
I(Crisis)	2.281	0.117	−3.339*	−3.321	5.889	−1.678	−11.863**	−16.458**
	(0.494)	(0.034)	(−1.749)	(−1.622)	(0.716)	(−0.196)	(−2.387)	(−2.480)
^{x} Institutional ownership	−1.622***	−2.633***	−0.505	−1.137**	−1.976**	−2.491**	0.309	−0.034
	(−3.613)	(−4.995)	(−1.156)	(−2.586)	(−2.261)	(−2.410)	(1.121)	(−0.119)
x I(Lockup period)		3.903		0.380		4.039		1.508
		(0.554)		(0.120)		(0.552)		(0.417)
x I(Redemption period > 90)		12.358		7.790*		12.496		8.510**
		(1.344)		(2.016)		(1.400)		(2.131)
Institutional ownership	1.708***	1.924***	0.275*	0.350**	1.764***	1.903***	0.171	0.175
	(4.516)	(5.664)	(1.942)	(2.332)	(4.217)	(5.001)	(1.243)	(1.343)
I(Lockup period)		−7.771**		0.511		−7.787**		0.305
		(−2.484)		(0.501)		(−2.493)		(0.300)
I(Redemption period > 90)		−3.571		−0.826		−3.639		−1.010
		(−1.135)		(−0.408)		(−1.174)		(−0.493)
Constant	−5.955*	0.239	−0.872	−1.292	−6.274	0.561	−0.198	0.510
	(−1.791)	(0.060)	(−0.566)	(−0.490)	(−1.691)	(0.118)	(−0.129)	(0.192)
Observations	1478	1474	1504	1477	1478	1474	1504	1477
Adj R^2	0.033	0.043	0.052	0.057	0.033	0.043	0.050	0.060

The table reports results from fund-level OLS regressions. The sample contains quarterly observations of hedge funds that appear in the match between 13F, ADV filings, and TASS. The dependent variable in Columns 1–4 is trades scaled by the value of the equity portfolio in the prior quarter; the dependent variable in Columns (5) through (8) is fund flows scaled by prior period AUM. Standard errors are clustered at the calendar quarter level. *t*-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 2004:Q1 to 2009:Q4.

pulling funds out of money market funds. Finally, Cella, Ellul, and Giannetti (2011) find that during market declines, institutional investors with short horizons (e.g., high turnover) reduce their equity positions more than do other investors.

5. Conclusion

The question of how the behavior of arbitrageurs is affected in times of market stress is fundamental to understanding how financial markets work. Hedge funds are the investor class most closely associated with arbitrage activity, and financial crises are the periods in which arbitrage activity is the most costly. In this article, we present new evidence about hedge funds' trading behavior during the 2007–2009 financial crisis. Our analysis shows that during this period hedge funds exited the equity market en masse. They reduced their equity holdings by about 6% in each of the third and fourth quarters of 2007, and by about 15% in each of the third and fourth quarters of 2008, on average.

Consistent with limits-of-arbitrage theories, our results suggest that hedge fund selloffs during the crisis were overwhelmingly driven by capital withdrawals on the part of investors and pressure by lenders. Furthermore, during the crisis, hedge funds more intensely closed positions in high-volatility stocks. This finding also supports the volatility abatement predictions of theories that postulate financial constraints for arbitrageurs. Also, hedge funds rushed to sell the most liquid securities in their portfolios, suggesting that they tried to limit the price impact during fire sales.

After describing hedge funds' selloffs, we compare their behavior to that of equity-focused mutual funds. The contrast with this other important group of institutional investors is meant to highlight hedge funds' specificity. We find that mutual funds' sales of stocks during the crisis as well as their capital outflows were an order of magnitude smaller than those of hedge funds. At the same time, the total returns of mutual funds were much worse during the crisis.

This raises the question of what differentiates investors in the two types of institutions. When studying the flow-performance sensitivity, we find that in response to past poor performance, hedge fund investors withdraw almost three times as much of their invested equity as do investors of mutual funds. The effect is significantly stronger for hedge funds that impose restrictions on investors' liquidity (lockup and redemption notice periods). This evidence suggests an equilibrium outcome in which hedge fund investors anticipate a future tightening of the redemption terms and pull their capital at the first signs of poor performance. This behavior keeps hedge fund managers in check and is reflected in an intense market-timing effort. In contrast, mutual-fund investors are relatively more passive, which translates into more inertial trading behavior on the part of their money managers.

In a final effort to understand the differences between the two asset classes, we conjecture that the presence of an institutional client base in hedge funds

underlies their fast-moving behavior. Exploiting the heterogeneity in hedge fund ownership, we find that hedge funds with a higher concentration of institutional clients sold more stocks and were subject to more redemptions during the crisis. The suggested interpretation is that sophisticated institutional investors react more quickly to the first signs of deterioration in market conditions. It is also plausible that the career concerns of money managers within hedge funds' institutional clients make them more sensitive to the initial changes in the performance of their investments.

Overall, the analysis outlines a picture in which hedge funds' arbitrage ability is limited by their fast-moving capital. These financial constraints forced hedge funds to run for the exits after the initial losses. This behavior may have amplified the initial negative shocks to asset prices, and it certainly did not stabilize markets. So, from the point of view of the global efficiency of the financial system, the behavior of hedge fund investors likely caused externalities to other market participants. Still, in relative terms, the behavior of hedge fund investors appears more sophisticated than that of mutual fund clients, who remained to bear the full brunt of a falling market.

Appendix: Variable Definitions

Aggregate Variables	Description
HF holdings over market cap (%)	Total stock market hedge fund holdings in $, scaled by the total market capitalization. Data source: 13F, CRSP, Thomson-Reuters.
Δ HF Holdings (%, share of equity holdings)	Quarterly change in total hedge fund holdings at the previous quarter's prices. For each stock, we total the changes in the number of shares owned by hedge funds and multiply by last-quarter prices. We aggregate across all stocks and scale by the value of the total hedge fund holdings in the previous quarter. Data source: 13F, CRSP, Thomson-Reuters.
Δ HF Holdings (%, share of market cap)	Quarterly change in total hedge fund holdings at the previous quarter's prices. For each stock, we total the changes in the number of shares owned by hedge funds and multiply by last-quarter prices. We aggregate across all stocks and scale by the total market capitalization in the previous quarter. Data source: 13F, CRSP, Thomson-Reuters.
MF holdings over market cap (%)	Total stock market mutual fund holdings in $, scaled by the total market capitalization. Data source: CRSP Mutual Funds, CRSP.
Δ MF Holdings (%, share of market cap)	Quarterly change in total mutual fund holdings at the previous quarter's prices. For each stock, we total the changes in the number of shares owned by mutual funds and multiply by last-quarter prices. We aggregate across all stocks and scale by the total market capitalization in the previous quarter. Data source: CRSP Mutual Funds, CRSP.

(*continued*)

Aggregate Variables	Description
Other institutional holdings over market cap (%)	Total stock market holdings by other institutions in $, scaled by the total market capitalization. "Other institutions" are defined as institutions that report the 13F, except for hedge funds and mutual funds. Data source: 13F, CRSP.
Δ Other institutional holdings (%, share of market cap)	Quarterly change in the total holdings of other institutions at the previous quarter's prices. For each stock, we total the changes in the number of shares owned by other institutions and multiply by last-quarter prices. We aggregate across all stocks and scale by the total market capitalization in the previous quarter. "Other institutions" are defined as institutions that report the 13F, except for hedge funds and mutual funds. Data source: 13F, CRSP.
Non-institutional holdings over market cap (%)	Total stock market holdings by non-institutional investors in $, scaled by the total market capitalization. For each stock, "Non-institutional investor ownership" is defined as one minus the fraction held by 13F institutions. Data source: 13F, CRSP Mutual Funds, CRSP, Thomson-Reuters.
Δ Non-institutional holdings (%, share of market cap)	Quarterly change in total non-institutional investor holdings at the previous quarter's prices. Calculated as the sum of the changes in the number of shares owned by non-institutional investors, multiplied by last-quarter prices, and scaled by the last-quarter total stock market capitalization. For each stock, "Non-institutional investor ownership" is defined as one minus the fraction held by 13F institutions. Data source: 13F, CRSP Mutual Funds, CRSP, Thomson-Reuters.
Short interest ratio (SIR) (%)	Total short interest in $, scaled by the total market capitalization. The total short interest is obtained by aggregating stock-level short interest. Data source: Compustat, CRSP, Exchanges.
Δ Short interest ratio (Δ SIR) (%, share of short interest)	Quarterly change in the total short interest at the previous quarter's prices. Calculated as the sum of the changes in stock-level short interest across stocks, multiplied by the previous quarter's prices, and scaled by the total short interest in the previous quarter. Data source: Compustat, CRSP, Exchanges.
Δ Short interest ratio (Δ SIR) (%, share of total shares outstanding)	Quarterly change in the total short interest, at the previous quarter's prices. Calculated as the average of the changes in short interest across stocks, as a percentage of their total shares outstanding. Data source: Compustat, CRSP, Exchanges.
Stock-level Data	
Total hedge fund holdings (%)	The total number of shares owned by hedge funds, scaled by the total shares outstanding. Data source: TASS.
Δ Total hedge fund holdings (%)	Quarterly change in the stock's hedge fund holdings. Calculated as the change in the number of shares owned by hedge funds over the quarter, scaled by the total shares outstanding. Data source: TASS.
Short interest ratio (SIR) (%)	Short interest (the sum of shares shorted) scaled by the total shares outstanding. Data source: Compustat, Exchanges.

(*continued*)

Aggregate Variables	Description
Δ Short interest ratio (SIR) (%)	Quarterly change in the stock's short interest. Calculated as the change in the number of shares shorted over the quarter, scaled by the total shares outstanding. Data source: Compustat, Exchanges.
Volatility	Previous 24-month return volatility. Data source: CRSP.
High volatility indicator	Indicates whether the stock has an above-median volatility within the month.
Amihud ratio	Stock liquidity is measured by the average ratio of the absolute value of daily returns to daily volume in the quarter (Amihud 2002). Data source: CRSP.
High Amihud ratio indicator	Indicates whether the stock has an above-median Amihud ratio within the month.
Size ($ million)	Market capitalization in $m. Data source: CRSP.
High size indicator	Indicates whether the stock has an above-median size within the month.
Book-to-market	Book value of assets (from the most recent 10Q filing) divided by the market value of equity at quarter end. Data source: Compustat, CRSP.
High book-to-market ratio indicator	Indicates whether the stock has an above-median book-to-market within the month.
Past 6m ret	Cumulative past six-month returns. Data source: CRSP.
High past 6m ret indicator	Indicates whether the stock has an above-median past 6-month return within the month.
Hedge-fund-level Data	
Selloff quarter	Indicator variable for 2007:Q3–Q4, 2008:Q3–Q4.
Pre-crisis	Indicator variable for 2004:Q1–2007:Q2.
Crisis	Indicator variable for 2007:Q3–2008:Q4.
Post-crisis	Indicator variable for 2009:Q2–2009:Q4.
Δ HF Holdings (%, share of equity holdings)	The value of shares added to a hedge fund's portfolio multiplied by the previous quarter's prices minus the value of shares sold from the portfolio multiplied by the previous quarter's prices, scaled by the total value of the equity portfolio in the previous quarter. Data source: CRSP, 13F, Thomson-Reuters.
Fund flows (%, share of AUM)	Quarterly change in assets under management less the total returns over the quarter divided by assets under management in the previous quarter. Data source: TASS.
Hedge Fund total return (%)	Total return to investors (as reported). Data source: TASS.
Equity portfolio return (%)	Quarterly returns based on the quarterly change in the hedge fund long equity holdings from 13F, assuming that trades occur at quarter-end prices. Data source: CRSP, 13F, Thomson-Reuters.
Assets under management (log(AUM))	Logged assets under management (AUM) as reported in TASS. Data source: TASS.
Average (Avg) leverage	Average leverage, as reported in TASS in August 2007. Data source: TASS.

(*continued*)

Aggregate Variables	Description
Multi-asset strategy dummy	A dummy for whether the hedge fund has more than 50% of its AUM in one of the following strategies: convertible arbitrage, emerging markets, fixed income arbitrage, fund of funds, global macro, managed futures, or multi-strategy. Data source: TASS.
Lockup period indicator	An indicator of whether the fund has a lockup period: a period following an investment during which investors are not allowed to redeem their investment (in months). Data source: TASS.
Redemption period >90 days indicator	An indicator of whether the sum of redemption notice and redemption frequency exceeds 90 days. Data source: TASS.
Frank	3-month performance ranking between 0 and 1. Sorting could be across all hedge funds on a particular date, or within a style-date. Data source: TASS.
TRank1	The minimum between 1/3 and FRank. Data source: TASS.
TRank2	The minimum between 1/3 and FRank – TRank1. Data source: TASS.
TRank3	The minimum between 1/3 and FRank – TRank1 – TRank2. Data source: TASS.
Hedge Fund indicator	An indicator of whether the entity is a hedge fund (as opposed to a mutual fund).
Hedge Fund with constraints indicator	Indicates whether the hedge fund has liquidity restrictions due to a lockup period or because their redemption notice period is longer than 30 days. Data source: TASS.
Institutional ownership	Institutional ownership calculated using self-reported data on ADV filings. Investors are considered institutional if they are not individuals or high-net-worth individuals. Data source: ADV.
Mutual Funds	
Mutual funds' quarterly returns	Quarterly returns. Data source: CRSP Mutual Fund Database.
Mutual fund flows	The amount of investor funds that entered/exited mutual funds in a particular quarter. Calculated as the different in assets under management on quarter t minus the assets under management on quarter $t-1$ times $(1+r)$, where r is the return of the mutual fund. Data source: CRSP Mutual Fund Database.
Mutual fund trades	The aggregate net change in mutual funds' holdings. Calculated as the change in the total number of shares multiplied by the last quarter's prices. Data source: CRSP, 13F.
Frank	3-month performance ranking between 0 and 1. Sorting could be across all mutual funds on a particular date. Data source: CRSP Mutual Fund Database.
TRank1	The minimum between 1/3 and FRank. Data source: CRSP Mutual Fund Database.
TRank2	The minimum between 1/3 and FRank – TRank1. Data source: CRSP Mutual Fund Database.
TRank3	The minimum between 1/3 and FRank – TRank1 – TRank2. Data source: CRSP Mutual Fund Database.

Appendix Table A1. The determinants of hedge fund trades: Predicted flows

	Dependent variable: Δ HF equity portfolio (%)				
	Investor redemptions		Lender Pressure		All financial constraints
	(1)	(2)	(3)	(4)	(5)
Selloff quarter	−11.078***	−5.238	−12.243***	−6.637	−1.406
	(−3.386)	(−1.248)	(−4.606)	(−1.387)	(−0.212)
× Predicted flows (q+1)		0.789**			1.040**
		(2.284)			(2.670)
× Avg. leverage				−6.471*	−5.403*
				(−1.863)	(−1.940)
Predicted flows (q+1)		0.698***			0.437
		(3.382)			(1.502)
Avg. leverage				3.792**	3.752**
				(2.509)	(2.487)
Constant	10.002***	10.407***	10.622***	7.401***	7.747***
	(5.810)	(6.220)	(6.640)	(3.542)	(3.747)
Observations	1838	1838	1180	1180	1180
Adj R^2	0.011	0.028	0.013	0.018	0.033

The table reports results from the OLS fund-level regressions in which the dependent variable is hedge fund trades as a fraction of the hedge fund equity portfolio, evaluated at prior-quarter prices. The explanatory variables include the selloff quarter dummy and the level and interactions of predicted fund flows (as of quarter $q+1$), and average leverage. Selloff quarters are 2007:Q3–Q4 and 2008:Q3–Q4. Predicted flows are the fitted values from a regression of flows in quarter $q+1$ on to total hedge fund returns in quarters q, $q-1$, and $q-2$. Standard errors are clustered at the calendar quarter level. t-statistics are reported in parentheses. ***, **, and * denote statistical significance at the 1%, 5%, and 10% levels, respectively. The sample period is 2004:Q1 to 2009:Q4.

References

Agarwal, V., N. Daniel, and N. Y. Naik. 2004. Flows, Performance, and Managerial Incentives in Hedge Funds. Working Paper, Georgia State University and London Business School.

———. 2009. Role of Managerial Incentives and Discretion in Hedge Fund Performance. *Journal of Finance* 64:2221–56.

Agarwal, V., V. Fos, and W. Jiang. 2010. Inferring Reporting Biases in Hedge Fund Databases from Hedge Fund Equity Holdings. Working Paper, Columbia University.

Agarwal, V., and N. J. Naik. 2004. Risk and Portfolio Decisions Involving Hedge Funds. *Review of Financial Studies* 17:63–98.

Amihud, Y. 2002. Illiquidity and Stock Returns: Cross-section and Time-series Effects. *Journal of Financial Markets* 5:31–56.

Anand, A., P. Irvine, A. Puckett, and K. Venkataraman. 2010. Market Crashes and Institutional Trading. Working Paper, Syracuse University.

Ang, A., S. Gorovyy, and G. B. van Inwegen. 2010. Hedge Fund Leverage. Working Paper, Columbia University.

Aragon, G. O., and P. Strahan. Forthcoming 2011. Hedge Funds as Liquidity Providers: Evidence from the Lehman Bankruptcy. *Journal of Financial Economics*.

Baele, L., G. Bekaert, and K. Inghelbrecht. 2010. The Determinants of Stock and Bond Return Comovements. *Review of Financial Studies* 23:2374–428.

Baquero, G., and M. Verbeek. 2009. A Portrait of Hedge Fund Investors: Flows, Performance, and Smart Money. Working Paper, ESMT European School of Management and Technology and Erasmus University.

Billio, M., M. Getmansky, and L. Pelizzon. 2010. Crisis and Hedge Fund Risk. Working Paper, University of Venice.

Billio, M., M. Getmansky, A. W. Lo, and L. Pelizzon. 2010. Econometric Measures of Systemic Risk in the Finance and Insurance Sectors. Working Paper, Massachusetts Institute of Technology.

Boehmer, E., and C. M. Jones. 2008. Which Shorts Are Informed? *Journal of Finance* 63:491–527.

Boyson, N. M., J. Helwege, and J. Jindra. 2010. Crises, Liquidity Shocks, and Fire Sales at Financial Institutions. Working Paper, Northeastern University.

Boyson, N. M., C. W. Stahel, and R. M. Stulz. 2010. Hedge Fund Contagion and Liquidity. *Journal of Finance* 65:1789–816.

Brown, D. B., B. I. Carlin, and M. S. Lobo. 2010. Optimal Portfolio Liquidation with Distress Risk. *Management Science* 56:1997–2014.

Brown, G. W., J. Green, and J. R. M. Hand. 2010. Are Hedge Funds Systemically Important? Working Paper, University of North Carolina at Chapel Hill.

Brunnermeier, M. K., and S. Nagel. 2004. Hedge Funds and the Technology Bubble. *Journal of Finance* 59:2013–40.

Brunnermeier, M. K., and L. H. Pedersen. 2009. Market Liquidity and Funding Liquidity. *Review of Financial Studies* 22:2201–38.

Calvet, L. E., J. Y. Campbell, and P. Sodini. 2009. Fight or Flight? Portfolio Rebalancing by Individual Investors. *Quarterly Journal of Economics* 124:301–48.

Campbell, J. Y., T. Ramadorai, and A. Schwartz. 2009. Caught on Tape: Institutional Trading, Stock Returns, and Earnings Announcements. *Journal of Financial Economics* 92:66–91.

Cao, C., Y. Chen, B. Liang, and A. W. Lo. 2009. Can Hedge Funds Time Market Liquidity? Working Paper, Pennsylvania State University.

Cella, C., A. Ellul, and M. Giannetti. 2011. Investors' Horizons and the Amplification of Market Shocks. Working Paper, Stockholm School of Economics and Indiana University.

Chevalier, J., and G. Ellison. 1997. Risk-taking by Mutual Funds as a Response to Incentives, *Journal of Political Economy* 105:1167–200.

Chordia, T., A. Sarkar, and A. Subrahmanyam. 2005. An Empirical Analysis of Stock and Bond Market Liquidity. *Review of Financial Studies* 18:85–129.

Coval, J., and E. Stafford. 2007. Asset Fire Sales (and Purchases) in Equity Markets. *Journal of Financial Economics* 86:479–512.

Ding, B., M. Getmansky, B. Liang, and R. Wermers. 2009. Share Restrictions and Investor Flows in the Hedge Fund Industry. Working Paper, State University of New York at Albany.

Fama, E. F., and K. R. French. 1992. The Cross-section of Expected Stock Returns. *Journal of Finance* 47:427–65.

———. 1993. Common Risk Factors in the Returns on Stocks and Bonds. *Journal of Financial Economics* 33:3–56.

Fung, W., and D. A. Hsieh. 1997. Empirical Characteristics of Dynamic Trading Strategies: The Case of Hedge Funds. *Review of Financial Studies* 10:275–302.

———. 2004. Hedge Fund Benchmarks: A Risk-based Approach. *Financial Analyst Journal* 60:65–80.

Getmansky, M., A. W. Lo, and I. Makarov. 2004. An Econometric Model of Serial Correlation and Illiquidity in Hedge Fund Returns. *Journal of Financial Economics* 74:529–610.

Goetzmann, W. N., J. E. Ingersoll, and S. A. Ross. 2003. High-water Marks and Hedge Fund Management Contracts. *Journal of Finance* 58:1685–718.

Goldman Sachs. 2010. Hedge Fund Monitor. *2010Q2 Portfolio Strategy Report*.

Goyenko, R. 2006. Stock and Bond Pricing with Liquidity Risk. Working Paper, McGill University.

Goyenko, R., and A. Ukhov. 2009. Stock and Bond Market Liquidity: A Long-run Empirical Analysis. *Journal of Financial and Quantitative Analysis* 44:189–212.

Griffin, J., and J. Xu. 2009. How Smart Are the Smart Guys? Unique View from Hedge Fund Stock Holdings. *Review of Financial Studies* 22:2531–70.

Gromb, D., and D. Vayanos. 2002. Equilibrium and Welfare in Markets with Financially Constrained Arbitrageurs. *Journal of Financial Economics* 66:361–407.

———. 2010. Limits of Arbitrage: The State of the Theory. *Annual Review of Financial Economics* 2:251–75.

Hau, H., and S. Lai. 2011. The Role of Equity Funds in the Financial Crisis Propagation. Working Paper, INSEAD.

He, Z., I. G. Khang, and A. Krishnamurthy. 2010. Balance Sheet Adjustments in the 2008 Crisis. Working Paper, University of Chicago.

Hombert, J., and D. Thesmar. 2009. Limits of Limits of Arbitrage: Theory and Evidence. Working Paper, HEC.

Jegadeesh, N., and S. Titman. 1993. Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency. *Journal of Finance* 48:65–91.

Jotikasthira, C., C. Lundblad, and T. Ramadorai. 2009. Asset Fire Sales and Purchases and the International Transmission of Financial Shocks. Working Paper, Said Business School.

Khandani, A. E., and A. W. Lo. 2011. What Happened to the Quants in August 2007? Evidence from Factors and Transactions Data. *Journal of Financial Markets* 14:1–46.

Lamont, O. A., and J. C. Stein. 2004. Aggregate Short Interest and Market Valuations. *American Economic Review* 94:29–32.

Li, H., X. Zhang, and R. Zhao. 2011. Investing in Talents: Manager Characteristics and Hedge Fund Performances. *Journal of Financial and Quantitative Analysis* 46:59–82.

Lemke, T. P., and G. T. Lins. 1987. Disclosure of Equity Holdings by Institutional Investment Managers: An Analysis of Section 13(f) of the Securities Exchange Act of 1934. *Business Lawyer* 43:93–119.

Manconi, A., M. Massa, and A. Yasuda. 2010. The Behavior of Intoxicated Investors: The Role of Institutional Investors in Propagating the Crisis of 2007–2008. Working Paper, University of California at Davis.

Metrick, A., and G. B. Gorton. 2010. Haircuts. Working Paper, Yale University.

Mitchell, M., L. Pedersen, and T. Pulvino. 2007. Slow-moving Capital. *American Economic Review P&P* 97:215–20.

Mitchell, M., and T. Pulvino. 2011. Arbitrage Crashes and the Speed of Capital. Working Paper, CNH Partners.

Nagel, S. 2011. Evaporating Liquidity. Working Paper, Stanford University.

Sadka, R. 2010. Liquidity Risk and the Cross-section of Hedge-fund Returns. *Journal of Financial Economics* 98:54–71.

Scholes, M. 2000. Crisis and Risk Management. *American Economic Review* 90:17–21.

Shleifer, A., and R. W. Vishny. 1997. The Limits of Arbitrage. *Journal of Finance* 52:35–55.

Sias, R., L. Starks, and S. Titman. 2006. Changes in Institutional Ownership and Stock Returns: Assessment and Methodology. *Journal of Business* 79:2869–910.

Sirri, E. R., and P. Tufano. 1998. Costly Search and Mutual Fund Flows. *Journal of Finance* 53:1589–622.

Teo, M. 2011. The Liquidity Risk of Liquid Hedge Funds. *Journal of Financial Economics* 100:24–44.

Vayanos, D. 2004. Flight to Quality, Flight to Liquidity, and the Pricing of Risk. Working Paper, London School of Economics.

Wermers, R. 2000. Mutual Fund Performance: An Empirical Decomposition into Stock-picking Talent, Style, Transactions Costs, and Expenses. *Journal of Finance* 55:1655–95.

———. 2010. Money Fund Runs. Working Paper, University of Maryland.