Journal of Financial Economics 103 (2012) 570–587

Contents lists available at SciVerse ScienceDirect

Journal of Financial Economics

journal homepage: www.elsevier.com/locate/jfec

Hedge funds as liquidity providers: Evidence from the Lehman bankruptcy ☆

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ARTICLE INFO

Article history:
Received 6 August 2010
Received in revised form
12 April 2011
Accepted 21 June 2011
Available online 25 October 2011

JEL classification:
G2

Keywords:
Hedge fund
Market and funding liquidity

ABSTRACT

Hedge funds using Lehman as prime broker faced a decline in funding liquidity after the September 15, 2008 bankruptcy. We find that stocks held by these Lehman-connected funds experienced greater declines in market liquidity following the bankruptcy than other stocks; the effect was larger for ex ante illiquid stocks and persisted into the beginning of 2009. We find no similar effects surrounding the Bear Stearns failure, suggesting that disruptions surrounding bankruptcy explain the liquidity effects. We conclude that shocks to traders' *funding* liquidity reduce the *market* liquidity of the assets that they trade.

1. Introduction

How does trading by hedge funds and their access to funding liquidity affect market liquidity and the dynamics of asset prices? This question has been difficult to answer because hedge funds enter markets where profit opportunities are likely to be greatest. Thus, they may be more likely to trade in relatively illiquid markets, where temporary deviations of prices from fundamentals are larger and more persistent, and they may enter and exit trades as liquidity and pricing dynamics shift. Long-Term Capital Management (LTCM), for example, famously traded on strategies related to changes in liquidity, such as those that occur in the U.S. Treasury market, where yields predictably rise as bonds move from the 'on-the-run' classification (where they trade actively) to the 'off-the-run' classification (where they tend to be purchased by buy-and-hold investors).

This paper sidesteps the endogeneity of trading strategies by exploiting a 'natural' experiment, the Lehman Brothers bankruptcy, which constituted a plausibly exogenous adverse shock to some hedge funds' access to funding liquidity. Lehman Brothers acted as one of the major prime brokers prior to its bankruptcy on September 15, 2008. Prime brokers provide custodial services, securities lending services, and financing to their hedge fund customers. Prior to bankruptcy, Lehman had rehypothecated many of its hedge-fund clients' assets. When Lehman failed, many of these assets could not be returned, making it impossible for the funds to trade or to switch to a competing broker. As we document, the relative hazard rate of Lehman's hedge-fund clients more than *doubled* after the bankruptcy, relative to Lehman funds before the crisis. Lehman's demise hampered the ability of some hedge funds to trade their positions, leading to an increase in their failure rate.

In our main analysis, we show that stocks held by Lehman's hedge-fund clients prior to the bankruptcy

☆ We thank seminar participants at Boston College, Harvard University, Indiana University, The Federal Reserve Bank of New York, The Jackson Hole Conference, MIT, the participants at the 2010 meetings of the Western Finance Association, and the SEC.

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doi:10.1016/j.jfineco.2011.10.004

experienced unexpectedly large declines in market liquidity after the bankruptcy, compared to otherwise similar stocks not held by hedge funds exposed to Lehman Brothers. The overall price impact of trades on these stocks rose (i.e., the Amihud illiquidity index, equal to the ratio of absolute returns to dollar volume), as did their bid-ask spreads. Liquidity overall dropped sharply for all stocks; our cross-sectional result implies that stocks held by Lehman-connected hedge funds experienced larger declines in liquidity than other stocks. We also find strong evidence that prices of stocks held by the Lehman-connected funds fell during the first few weeks after the bankruptcy, and somewhat weaker evidence that they then had higher average returns for the subsequent months, suggesting higher liquidity risk required higher expected returns going forward.

The relative drop in liquidity is large both statistically and economically, and persists and even grows through the fourth quarter of 2008. We find no similar liquidity effects surrounding the Bear Stearns failure, suggesting that our results flow from disruptions surrounding bankruptcy rather than just the failure of a large broker-dealer. Institutional investors seemed to have supplied liquidity—or at least reduced the increase in demand for liquidity-during the post-Lehman stock market collapse. Lehman Brothers' hedge-fund customers were unable to fulfill this stabilizing role because they were constrained in their ability to trade their positions.

Figs. 1 and 2 illustrate our key result graphically. We report the average percentage change in the Amihud (2002) illiquidity index from the three months before to the three months after Lehman's bankruptcy. The index increased across the whole stock market as liquidity dried up across the board. Said slightly differently, stock-return volatility increased much more than trading volume due to greater price impact of trades in the less liquid environment that prevailed after September. But, as the figure shows, the decline in liquidity was larger for stocks held by hedge funds that used Lehman as their prime broker (Fig. 1). For stocks with illiquidity above the median during the pre-crisis months, the increase was

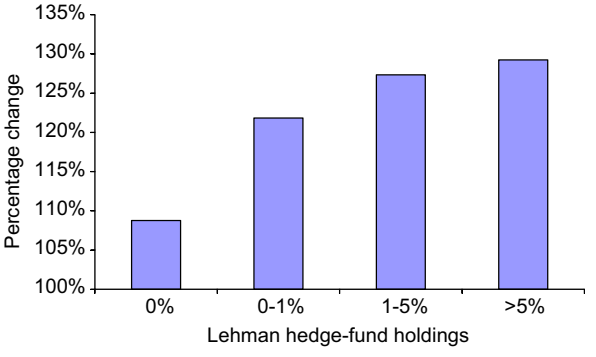

Fig.1. Percentage change in Amihud's price impact measure. This figure graphs the percentage change in the Amihud illiquidity index from the pre-Lehman (July 1–August 31, 2008) to the post-Lehman (September 15, 2008–December, 2008) bankruptcy periods. The stocks are separated into four groups based on the fraction owned by Lehman-connected funds as of June 30, 2008 from 13F filings.

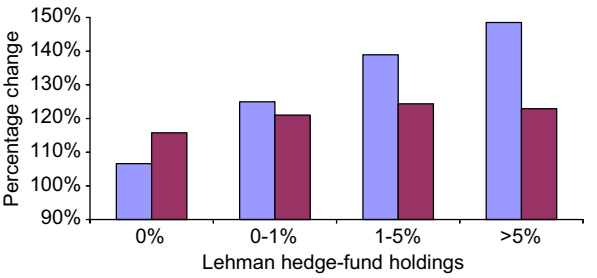

Fig. 2. Percentage change in Amihud's price impact measure by ex ante liquidity level. This figure graphs the percentage change in the Amihud illiquidity index from the pre-Lehman (July 1–August 31, 2008) to the post-Lehman (September 15, 2008–December, 2008) bankruptcy periods. The stocks are separated into eight groups: first based on the fraction owned by Lehman-connected funds as of June 30, 2008 from 13F filings, and second based on whether the stock was above or below the median Amihud index during the pre-crisis regime. The bars on the left represent stocks with an Amihud index above the sample median.

much more pronounced (Fig. 2). For example, illiquid stocks not held by Lehman-connected funds experienced an increase in illiquidity of about 105%, compared to an increase of almost 150% for stocks with more than 5% of their shares owned by these funds.

Our empirical strategy boils down to using the Lehman bankruptcy as an instrument for a funding shock. This raises the broader question: Does market liquidity fall when hedge funds fail generally? While we do report results consistent with this notion, testing how failure affects liquidity runs into several problems. In contrast to the Lehman bankruptcy, we cannot pinpoint the exact timing of failure, which we measure based on funds dropping out of our Lipper TASS hedge-fund database (TASS). Returns enter TASS with a lag, and funds sometimes report their last return several months before failure. For example, the Bear Stearns High-Grade Structured Credit Fund and the High-Grade Structured Credit Enhanced Leveraged Funds both failed in July of 2007 but reported their last return to TASS in April of that year. Hedge fund failures (based on TASS-defined failure) are also preceded by below-average returns and above-average outflows, suggesting two kinds of endogeneity. First, funds may sell their more-liquid stocks prior to failure to meet investor redemptions. Second, poor performance of assets held by hedge funds may be correlated with changes in the liquidity of those stocks. Our approach avoids these problems because Lehman's demise occurred suddenly, because we know exactly when to search for liquidity and pricing effects, and because subprime lending explains the failure, rather than problems associated with the hedge-fund brokerage business.

Our results provide support for models linking the funding liquidity of traders to the market liquidity of the assets that they trade. Finding a causal link from funding to market liquidity is difficult empirically because there is a two-way feedback between them. Comerton-Forde, Hendershott, Jones, Moulton, and Seasholes (2010) show that shocks to market-makers' balance sheets can affect market liquidity. In our case, shocks to funding liquidity of traders occurred through their links to Lehman

Brothers because of the bankruptcy. As a consequence, prices fell and market liquidity was reduced. Brunnermeier and Pedersen (2009) emphasize the problem of downward liquidity spirals, whereby declines in liquidity in one market can spill over into other markets because traders' ability to borrow becomes constrained. Such liquidity spirals may help explain how small shocks can reverberate across the entire global financial system. Our finding that the effects on market liquidity persist and even grow for a time resonates with models of liquidity spirals, since the initial decline in funding liquidity worsens as market liquidity declines. We acknowledge, however, that our identification strategy cannot trace out the full dynamics of such spirals beyond the initial shock following the Lehman bankruptcy.

We then decompose total price impact into its permanent and transitory components, as in Glosten and Harris (1988), Brennan and Subrahmanyam (1996), Chordia, Roll, and Subrahmanyam (2001), and Sadka (2006). The permanent component of price impact reflects costs faced by uninformed market makers when they trade against better-informed investors. Intuitively, prices increase permanently in response to buy-side volume to reflect the probability that a given buy order implies private information about fundamentals. Vice versa for sell orders. The temporary component – that part of price impact related to short-term shocks to volume – reflects inventory holding costs to market makers.

We find opposing results when we disentangle the overall price impact. The permanent component falls for stocks held by Lehman's hedge-fund clients, while the temporary component rises. The result suggests that hedge-fund trading *increases* liquidity relative to short-term shocks to volume, presumably because they trade patiently and are able to absorb some of the variation in liquidity demands from high-frequency 'noise trades.' Hedge funds also invest in private information themselves, however, meaning that some of their trades impose adverse selection costs on other less-informed liquidity suppliers (market makers). Thus, the permanent component of price impact *decreases* for stocks held by Lehman's hedge-fund clients, suggesting that information content in trades falls.

The results suggests that the long-term growth of hedge-fund trading has had mixed effects on overall liquidity—increasing short-term liquidity but raising the adverse selection costs to market makers. The results are consistent with hedge funds earning high returns both because they supply liquidity to noise traders and because they invest in private information.

The remainder of our paper is organized into two main sections and a brief conclusion. Section 2 describes the role of the prime broker for hedge funds. We report simple comparisons of funds connected and not connected to Lehman, and then estimate a hazard model of fund survival as a function of affiliation with Lehman, controlling for performance measures. In Section 3, we compare changes in market liquidity and returns of U.S. stocks as a function of the amount of pre-crisis ownership in those stocks by the Lehman-affiliated funds. Section 4 concludes.

2. Lehman Brothers' bankruptcy and its hedge-fund clients

Lehman Brothers had become one of the major prime brokers for hedge funds during the years leading up to its failure in 2008. Prime brokers provide their hedge-fund customers with cash management services, securities lending services, and financing services, among other things. The business of prime brokerage grew rapidly over the past ten years as assets under management at hedge funds took off. As has been well recognized, brokers bear substantial counterparty risk relative to their hedge-fund clients. Prime brokers routinely lend to hedge funds to support their long positions, holding those long positions as collateral. Rapid declines in collateral value can potentially expose the broker to losses, as famously occurred on a massive scale in the blow-up of LTCM in 1998.

What has been less well understood until recently, however, is that hedge funds are in turn exposed to the failure of their prime broker. For example, prime brokers sometimes lend securities purchased by hedge funds to other investors in a process known as rehypothecation. Rehypothecation generates fees for the prime broker, but it also creates counterparty risk for the hedge fund by making it difficult for the fund to re-claim its securities if the broker fails. As one hedge-fund manager commented in the wake of Lehman's failure, 'If you gave your assets to Lehman as collateral and they lent those out, then more than one person has a claim on those assets. Everyone passes around the security, then the music stops, there is one chair to sit on and too many people who want to sit on it (*Euromoney*, November 2008).'[1]

The Oak Group was a medium-sized hedge fund that used Lehman Brothers International, based in London, as its prime broker. Oak Group's demise illustrates how the Lehman bankruptcy affected its hedge-fund customers. Oak group had $22 million in long positions matched with $22 million in short positions, plus $16 million in cash in a margin account. All of these positions were held by Lehman, who had lent out the $22 million in Oak Group's long positions (an example of rehypothecation). Thus, when Lehman failed, Oak Group could not regain its securities or its cash; they became a general creditor of Lehman Brothers. As John James, the head of Oak Group, said, 'Without those securities, my strategy has been ruined. Had we had the securities and been able to continue trading, we would have been up about 6% over the last 6 weeks.'

Overall, Lehman had lent out in aggregate $22 billion in securities when it entered bankruptcy (*Euromoney*,

[1] U.S. securities law requires that prime brokers disclose this practice and receive written permission from customers, but no such law exists in London, where much of the hedge fund business has moved. In fact, Lehman's main prime brokerage business was run out of London in its subsidiary, Lehman Brothers International (Aitken and Singh, 2009). The lighter regulation of prime brokers in the U.K. allowed them to extend credit on more favorable terms to their clients, but also likely increased the counterparty risk to hedge funds and other investors.

2008). If many of its clients could not trade, the market liquidity of positions held by those clients could reasonably be expected to decline. In fact, this is precisely what is predicted in Brunnermeier and Pedersen (2009). Moreover, if liquidity is a priced risk factor, then shocks to market liquidity could lower asset prices, and raise expected returns going forward (e.g., Amihud and Mendelson, 1986; Amihud, 2002; Pastor and Stambaugh, 2003; Acharya and Pedersen, 2005).

2.1. Measuring Lehman-exposed hedge funds and their holdings

To implement our empirical tests, we first want to identify those hedge funds that continued to use Lehman as their prime broker when Lehman entered bankruptcy in September of 2008. Second, we want to identify the positions held by those hedge funds. Together these data will allow us to test for spillovers from the bankruptcy to those assets. We are able to build proxies for both of these steps from available data. The proxies are imperfect, but this problem will tend to attenuate rather than amplify our results.

Our main source for hedge-fund data is TASS, which includes a history of returns as well as a series of hedge-fund characteristics. TASS updates the data daily, with changes from one version to the next reflecting the addition of new funds reporting to the database, updated performance data of existing funds, and movements of a fund from the live folder (i.e., funds that are still reporting) to the graveyard folder (i.e., funds that have ceased reporting). The most recent version of the database is available for daily download from the Web site, but prior versions are not currently available. We have downloads of the database in 2002 (January and September), 2003 (January), 2005 (December), and 2006 (April), and we have multiple snapshots in 2007, 2008, and 2009. In all, we have 102 snapshots of the TASS data. Most important, we have a snapshot of TASS in August 2008, just prior to Lehman's bankruptcy.

TASS contains information on the prime broker, along with other affiliated companies (e.g., Bank, Custodian, Administrator, Management Firm, Auditor, Legal), in the 'Companies.txt' file. Since funds sometimes change their use of brokers, we use all available versions of the database to construct a panel of fund affiliations with their prime broker. Affiliated prime brokers are identified when the string observation in the 'Company Type' field equals 'Prime Broker.' We identify 1,556 unique non-missing entries in the 'CompanyName' field for the prime broker company type. We clean the reported names of the fund affiliates because the same broker might be coded differently by two different funds. After hand-checking the raw list, we end with a final master list containing 381 unique prime brokers.

Table 1 reports the names and average market shares of the top ten prime brokers over time. Market share is computed across all available versions of the database and averaged across each year; we define market share as the ratio of the number of a prime broker's affiliated funds divided by total funds reporting a non-missing prime broker affiliation. Since the fall of 2008, some large investment banks have lost market share, leading to a decline in prime brokerage market concentration. The share of the top three brokers held steady at about 50% until 2007, then fell to 42% by 2009. And, eight of the top ten brokers lost market share. The two exceptions, Deutsche Bank and Credit Suisse First Boston, both experienced a slight increase in market share over this period. As we have argued above, and as we will show

Table 1
Top ten hedge fund prime brokers by market share.
This table lists the ten largest prime brokers in each of the 6 years of available versions of the TASS database. Market share is computed for each version of the database as the proportion of funds affiliated with a given prime brokerage. We drop funds that do not report any prime brokerage affiliate. The reported values are market share averages across versions by year.

2002	2003	2005
18.16% Bear Stearns	18.05% Bear Stearns	19.41% Morgan Stanley
16.24% Morgan Stanley	16.43% Morgan Stanley	18.38% Goldman Sachs
13.65% Goldman Sachs	14.47% Goldman Sachs	13.98% Bear Stearns
4.30% Bank of America	5.81% ABN AMRO	8.51% UBS
3.67% ABN AMRO	5.14% Bank of America	6.03% Bank of America
3.65% Morgan Stanley Dean Witter	2.91% Merrill Lynch	3.33% Lehman Brothers
3.40% Merrill Lynch	2.64% Morgan Stanley Dean Witter	3.25% Citigroup
2.77% Man Group	2.50% Man Group	3.12% Credit Suisse First Boston
2.23% ING Group	1.96% Salomon Smith Barney	2.69% Deutsche Bank
1.85% Salomon Smith Barney	1.62% Credit Suisse First Boston	2.39% Man Group
2006	**2007**	**2008**
19.67% Morgan Stanley	20.67% Morgan Stanley	20.60% Morgan Stanley
18.24% Goldman Sachs	17.21% Goldman Sachs	16.64% Goldman Sachs
13.21% Bear Stearns	12.00% Bear Stearns	9.13% Bear Stearns
8.61% UBS	8.24% UBS	8.58% UBS
5.53% Bank of America	4.53% Bank of America	4.14% Deutsche Bank
3.88% Citigroup	4.15% Citigroup	3.90% Citigroup
3.55% Lehman Brothers	3.68% Deutsche Bank	3.46% Merrill Lynch
3.29% Credit Suisse First Boston	3.58% Credit Suisse First Boston	3.37% Credit Suisse First Boston
2.57% Deutsche Bank	3.31% Lehman Brothers	3.04% Bank of America
2.36% Man Group	2.96% Merrill Lynch	2.36% Lehman Brothers

Table 2
Summary statistics for Lehman vs. non-Lehman hedge funds.

This table summarizes performance and characteristic variables for funds reporting to TASS in 2008, and for the merged sample with June 2008 13F filers. Variables are summarized for subgroups depending on whether the fund lists Lehman Brothers as a prime broker in the last report to TASS prior to September 2008. We drop funds that do not report any prime brokerage affiliate. Liquidated in 2008 indicates whether the fund's final non-missing reported return to TASS occurs in 2008. Monthly return is the average monthly return measured over 2007. Monthly flow is the average monthly percentage net asset flow to the fund measured over 2007. Net assets is the estimated asset value reported to TASS at the end of 2007. Fund style categories are indicator variables corresponding to the reported fund style. For the characteristics on holdings (13F sample), we summarize share-weighted averages of individual stock positions. Stock market capitalization is measured as of June 2008. Bid-ask spread and Amihud illiquidity are daily averages from June through the end of August 2008. Market and liquidity betas are the regression coefficients on market returns and market liquidity factors, estimated over January 2005 to June 2008 with monthly returns. Stock characteristics for a given manager are averages across all positions using the manager's portfolio weights. A '+' denotes statistical significance at the 10% level, '*' at the 5% level, and '**' at the 1% level.

	Lehman hedge funds		Other hedge funds			
Panel A: Tass sample	*N*	Mean	*N*	Mean	Mean difference	*t*-Statistic for difference of means
Liquidated in 2008 dummy	77	45.45%	2,666	31.73%	13.72%	2.54**
Monthly return	77	−1.22%	2,664	−1.53%	0.31%	0.91
Monthly flow	52	−1.71%	2,086	−0.50%	−1.21%	1.80+
Logarithm of net assets	46	17.50	1,478	18.02	−0.53	1.98*
Lagged variables measured in 2007						
Monthly return	76	0.44%	2,626	0.93%	−0.48%	1.80+
Monthly flow	53	0.21%	2,039	1.73%	−1.52%	1.88*
Logarithm of net assets	35	17.4	992	18.09	−0.69	2.36*
Fund style categories						
Convertible arbitrage	74	8.11%	2,645	2.57%	5.54%	2.89**
Dedicated short bias	74	0.00%	2,645	0.57%	−0.57%	0.65
Emerging markets	74	0.00%	2,645	6.20%	−6.20%	2.21*
Equity market neutral	74	6.76%	2,645	6.50%	0.25%	0.09
Event driven	74	6.76%	2,645	8.13%	−1.37%	0.43
Fixed income arbitrage	74	13.51%	2,645	4.57%	8.94%	3.55**
Fund of funds	74	1.35%	2,645	9.00%	−7.65%	2.29*
Global macro	74	10.81%	2,645	3.93%	6.88%	2.94**
Long/short equity hedge	74	35.14%	2,645	45.10%	−9.97%	1.70+
Managed futures	74	4.05%	2,645	6.65%	−2.60%	0.89
Multi-strategy	74	13.51%	2,645	6.73%	6.78%	2.27*
Panel B: Hedge fund investment companies filing 13F in June 2008						
Log of stock market capitalization (millions)	29	22.59	473	22.40	0.19	0.44
Bid-ask spread	29	0.19%	473	0.22%	−0.03%	−0.50
Amihud illiquidity	29	5.33%	473	26.93%	−21.61%	−0.69
Market return beta	29	1.13	473	1.13	0.00	0.04
Market liquidity beta	29	24.88	473	16.47	8.41	1.33

empirically below, the Lehman bankruptcy led to unexpectedly high failure rates for its hedge-fund customers (controlling for performance). The evidence here is consistent with a heightened concern among hedge funds about counterparty risk. Many funds have apparently moved away from investment banks regarded as risky in search for a secure haven for their assets (Ebers, 2008).

Panel A of Table 2 summarizes various characteristics of funds that reported at least one return observation to TASS in 2008. Since our last download before September 15, 2008 was on August 2, 2008, we know that these classifications are very close to what actually occurred as Lehman entered bankruptcy. The table makes univariate comparisons, depending on whether the fund's reported prime brokerage affiliation is Lehman Brothers. Some hedge funds in TASS report more than one broker; among these, we define a fund as 'Lehman-connected' if Lehman is one of the reported brokers. We define non-Lehman funds as those reporting a prime brokerage affiliation other than Lehman Brothers (we drop funds that do not report a prime broker in TASS). The classification of each fund is determined using the fund's latest reported prime brokerage affiliation prior to September 2008. Failure itself is not directly observable in TASS, so we define failure by whether a fund stops reporting to the database. For example, we classify funds as having failed in 2008 if its last reported return appears in 2008 as our proxy for fund liquidation (first row of Table 2). Since advertising is a primary reason for funds to report performance data to the database, some funds may drop out of TASS even if they have not failed. Getmansky, Lo, and Mei (2004), however, argue that over 90% of funds that stop reporting from the database are plausibly liquidated funds.[2]

The simple univariate comparisons suggest that Lehman funds failed more during the crisis period, which we explore more formally in the next section.[3] In addition,

[2] We use TASS data through June 2009 to identify funds that fail in 2008 because funds sometimes delay several months in reporting returns. Moreover, as noted in the introduction, pinpointing the exact timing of failure is not possible from TASS because the last reported return may occur several months before actual failure. Hence, we estimate the hazard model by fund-year rather than by fund-month.

[3] Fernando, May, and Megginson (2011) and Kovner (forthcoming) find that Lehman's bankruptcy also was followed by abnormal negative returns for their equity underwriting clients.

Lehman funds were slightly smaller and performed somewhat worse leading up the crisis than other funds. While at least 50% of the Lehman funds were actively engaged in equity-based strategies (self-reported styles: convertible arbitrage, long-short equity, and equity market neutral), they were somewhat more likely than the average fund to focus on fixed income markets. We will account for these differences using a matching strategy in one of our falsification tests below.

To build data on Lehman and non-Lehman equity holdings, we use data from TASS-reporting hedge funds that also filed the June 2008 13F. Although hedge funds are generally not required to disclose their complete holdings to the public, Section 13(f) of the Securities Act of 1933 requires all investment advisors managing more than $100 million to file their long positions in stocks on Form 13F at the end of every quarter. We use these filings as of June 2008 to build our key explanatory variable ($Lehman\text{-}HF\ holdings_i$).[4] From TASS, we are able to identify 77 hedge funds that report using Lehman Brothers as their prime broker in 2008. We augment the TASS sample with twelve other hedge-fund investment advisors that the popular press identifies as having had a prime brokerage affiliation with Lehman Brothers at the time of bankruptcy. We find these by searching Lexis–Nexis from September 1, 2008 until the end of 2008 on the words 'hedge fund,' 'Lehman,' and 'prime broker.'[5] In robustness tests, however, we drop these additional twelve funds to rule out the possibility that results were driven by non-random placement of funds in news articles. The final sample contains 29 advisors that have filed a Form 13F with the Securities and Exchange Commission (SEC) in the second quarter of 2008. We retrieve their stock holdings from the 13F filings and compute, for each stock, the fraction of total shares outstanding owned by these Lehman-affiliated hedge-fund advisors. In aggregate, these investment advisors held about $150 billion in total stocks as of the middle of 2008.

In Panel B of Table 2, we use the 13F data to compare the market β, and three measures of liquidity for each fund's equity holdings. The two liquidity level variables, the bid-ask spread and Amihud's illiquidity measure, are based on daily averages during the 3 months leading up to Lehman's bankruptcy. We use a liquidity β to measure liquidity risk, following Amihud (2002) and Acharya and Pedersen (2005). These βs come from a set of time-series regressions (one per stock), with each stock's return series as dependent variable and the market liquidity factor and market return as explanatory variables.[6] The coefficients on the market liquidity factor and market returns are taken as the stock's market liquidity and market return βs, respectively. The market liquidity factor and both market βs are estimated for each stock using all available data between January of 2005 and June of 2008. The comparison across hedge-fund groups (Panel B) suggests that there are no systematic differences in the average stocks held by Lehman-connected vs. non-Lehman hedge funds. Both tend to tilt slightly toward larger and above-average risk stocks, but there are no statistically significant differences across the two groups.

2.2. Hazard model of hedge-fund failure

The raw data clearly suggest that Lehman's bankruptcy harmed its hedge-fund customers. For example, 45% of the 77 Lehman-affiliated funds appear to have been liquidated in 2008, compared to 32% for other funds (Panel A of Table 2). Table 2 also shows that Lehman funds had lower average returns and net flows in 2007 and 2008. Lehman funds typically manage fewer assets than non-Lehman funds, and are also associated with shorter redemption notice and lockup periods.

To validate the differences in raw liquidation rates, we report a proportional hazard model of the time to hedge-fund failure as a function of style, performance, size, flow, and prime-brokerage affiliation. Our estimation uses fund-year observations from 2002 to 2008. Although returns are available from 1994, the prime brokerage affiliation and fund characteristics are only available in cross-sectional 'snapshots' of the 102 versions of the database that we have downloaded. Therefore, since we cannot recover these affiliations before 2002, we start the sample in 2002 and update the information with each new version of the database. In the interim, between available versions of the database, we carry forward the prime brokerage and characteristics information from the most recently available version of the database. This approach has the appeal that our predictors are indeed in the information set when we classify surviving funds each year.

The time variable in our model equals the number of days since the first date each fund began to report in TASS. The time and failure variables yield the baseline hazard rate for our hedge-fund sample. We also include several explanatory variables that plausibly shift the baseline hazard rate, such as the natural logarithm of total assets under management and within-year averages of monthly fund returns and monthly net fund flows.

[4] In principle, we would like to observe the identity of all stocks that these hedge funds might potentially trade, either long or short. We use actual long positions as the best available proxy for these stocks. Brunnermeier and Nagel (2004) and Griffin and Xu (2009) also use Form 13F filings to study hedge funds' long equity positions. Even so, the required filings are at the level of the advisor, and therefore, a single filing might correspond to several hedge funds under management. Nevertheless, in the following analysis of 13 F equity holdings, we use the terms 'hedge fund' and 'hedge-fund advisor' interchangeably.

[5] We dropped two advisors (D.E. Shaw and Lansdowne Partners) from this search because the article commented that the fund's exposure to Lehman was negligible, two were dropped because they were imperfect matches (Schroder Alternative Solutions and Lazard), and one was dropped because Lehman was not the prime broker (Macquarie Funds Group).

[6] To build the liquidity betas, we first generate a monthly market liquidity factor (Amihud's measure) equal to the average liquidity across individual stocks, weighted by market capitalization at the start of the year. The monthly liquidity factor equals the residual from a regression of monthly liquidity on its past two monthly values. Our sampling criteria also follow Acharya and Pedersen (2005). To compute the liquidity factor in a given month, we only use stocks that are ordinary common shares (share codes less than 20), are listed on New York Stock Exchange or AMEX, have at least 15 return and volume observations, and have a beginning-of-month price between $5 and $1,000.

Table 3
Hazard model predicting exit of hedge funds from the market.

This table reports a semi-parametric Cox proportional hazard models that relate the survival of each hedge fund to its performance and its use of Lehman Brothers as prime broker. The model is applied to all hedge funds that reported at least one return to TASS between 2002 and 2008. The date of the first return reported to TASS by a fund is event-time zero. The failure of the fund is observed if it occurs before June 2009. Hedge funds are assumed to have failed if they stop reporting to the TASS database. A coefficient greater than one indicates an increasing relationship between the co-variate and the survival probability; a coefficient below one indicates the opposite. We report a *Z*-statistics that are asymptotically normally distributed under the null that the coefficient equals one. Fund assets, Lockup period, Notice period, and Lehman fund dummy are measured at the beginning of every year. Average fund return and average fund flow are within-year averages of monthly returns and fund flows. Standard errors are clustered at the fund-level. Style dummies are included in the final model. All explanatory variables except the dummies are standardized to have zero mean and unit variance. A '+' denotes statistical significance at the 10% level, '*' at the 5% level, and '**' at the 1% level.

	1	2	3	4	5	6
2008 Dummy	1.88	1.53	1.50	1.65	1.64	1.66
	(13.18)**	(6.81)**	(5.75)**	(7.03)**	(6.98)**	(7.14)**
Lehman fund dummy	0.67	0.65	0.47	0.46	0.47	0.43
	(1.94)+	(2.05)*	(2.68)**	(2.48)*	(2.43)*	(2.69)**
2008 Dummy*Lehman fund dummy	2.42	2.67	3.37	3.13	3.14	3.06
	(3.15)**	(3.57)**	(3.53)**	(3.18)**	(3.21)**	(3.12)**
Raw fund return	–	0.84	0.85	0.87	0.86	0.86
	–	(6.73)**	(5.64)**	(5.12)**	(5.30)**	(5.32)**
Percentage net fund flow	–	–	0.68	0.62	0.62	0.63
	–	–	(7.23)**	(8.19)**	(8.15)**	(8.17)**
Ln(Fund assets)	–	–	–	0.70	0.69	0.69
	–	–	–	(12.87)**	(12.99)**	(12.81)**
Ln(1+ Lockup period)	–	–	–	–	0.97	0.96
	–	–	–	–	(1.23)	(1.36)
Ln(1+Redemption notice period)	–	–	–	–	1.07	1.03
	–	–	–	–	(2.10)*	(0.90)
Hedge fund style fixed effects?	No	No	No	No	No	Yes
N	9,557	9,557	7,847	7,122	7,122	7,122

Robust *Z*-statistics in parentheses.

Total assets are measured at the end of the previous year and the average return and flow variables are measured at the end of the current year or, if the fund fails within the year, at the fund failure date. Net flows are calculated in the usual way as the monthly growth rate in assets under management after subtracting the growth in assets attributable to returns. We expect higher average returns, greater average flows, and larger fund size all to lead to a decrease in the hazard rate, and this would be reflected in hazard ratios (coefficients) less than one. We also include the natural logarithm of the lockup and redemption notice periods as explanatory variables. Aragon (2007) argues that share restrictions on hedge funds reduce non-discretionary trading costs and improve fund profitability. Therefore, it seems plausible that share restrictions may be associated with a lower hazard rate.

To validate our identification strategy–that is, to show that hedge funds were harmed by Lehman's collapse – we include a 2008 calendar-year indicator, an indicator equal to one if the fund's prime brokerage affiliation was with Lehman Brothers at the start of each year, and their interaction. A finding that 2008 is associated with a greater hazard ratio would not be surprising in light of extraordinary credit events during this period. Our main hypothesis is that 2008 was an especially difficult year for funds exposed to the Lehman Brothers' bankruptcy. The key variable of interest is thus the interaction between the year-2008 indicator and the indicator for Lehman affiliation. A coefficient greater than one for this variable would suggest that the hazard rate increased more in 2008 for hedge funds affiliated with Lehman Brothers than for other funds.[7]

The results strongly suggest that Lehman brought many of its customers down when it failed in September (Table 3). The hazard analysis shows that hedge-fund failure rates increased across the board in 2008—the year-2008 indicator enters with a coefficient of 1.5 or higher (depending on the model), meaning that failure rates increased by at least 50% in 2008 relative to the earlier years. Note that this increase goes beyond what one would predict based on performance, which was itself very poor during that year. The point estimates also suggest that Lehman-affiliated hedge funds were two to three times as likely to fail in 2008 compared to Lehman funds before the crisis.[8] Prior to 2008, however, there was a significantly lower failure rate for Lehman customers (i.e., the direct effect of the Lehman indicator is significantly less than one).[9] The other characteristics enter the

[7] Standard errors are clustered at the fund-level. Style dummies are included in the final model. All explanatory variables except the dummies are standardized to have zero mean and unit variance. We ignore assets under management that are not reported in either U.S. Dollars or Euros. Euros are converted to dollars using month-end dollar-to-euro exchange rates.

[8] We have also estimated a hazard model in which the effects of all variables are allowed to shift in 2008. The coefficient on the Lehman*2008 indicator remains between two and three in this unrestricted model.

[9] We have also estimated a similar model that includes a Bear Stearns indicator and its interaction with the 2008 dummy. This model

model as one would expect: larger funds, funds with greater net flow, and funds with better recent performance have lower hazard rates than others funds (i.e., the coefficients on these variables are significantly less than one). We find no effect of redemption restrictions or lockups on fund survival, however, this null result may reflect the endogeneity of these contract terms.[10]

3. Liquidity after the fall of Lehman

3.1. Estimation strategy

In this section we study whether the market liquidity of stocks held by Lehman-connected hedge funds declines following the Lehman Brothers collapse, relative to similar stocks not held by these funds. We test for a spillover from declines in the funding liquidity of investors (Lehman-connected hedge funds) to declines in the market liquidity of assets that they hold. These tests amount to a series of cross-sectional regressions with the following general structure:

$$\begin{aligned} \textit{Log Post}-\textit{crisis illiquidity}_i = {} & \alpha + \beta\, \textit{Log Pre}-\textit{crisis illiquidity}_i \\ & + \gamma^1\, \textit{Lehman}-\textit{HF holdings}_i + \gamma^2 \textit{Non} \\ & -\textit{Lehman HF holdings}_i \\ & + \gamma^3\, \textit{Other institutional holdings}_i \\ & + \textit{Pre}-\textit{crisis control variables}_i + \varepsilon_i, \end{aligned} \tag{1a}$$

where *Post-crisis illiquidity*$_i$, the dependent variable, equals either the bid-ask spread or Amihud's illiquidity measure, averaged over the period from September 15, 2008 to the end of the year.

If liquidity declines during the post-crisis period and if liquidity is a priced risk factor, then stock prices ought to fall initially and then offer higher returns going forward. To test for the initial price response, we estimate a parallel set of regressions to Eq. (1a) by replacing the illiquidity variables with the average daily return from September 15, 2008 to the end of the month:

$$\begin{aligned} \textit{Stock return}_i = {} & \alpha + \beta\, \textit{Log Pre}-\textit{crisis illiquidity}_i + \gamma^1\, \textit{Lehman} \\ & -\textit{HF holdings}_i + \gamma^2\, \textit{Non}-\textit{Lehman HF holdings}_i \\ & + \gamma^3\, \textit{Other institutional holdings}_i \\ & + \textit{Pre}-\textit{crisis control variables}_i + \varepsilon_i, \end{aligned} \tag{1b}$$

where i is an index across Nasdaq and NYSE stocks. Below, we characterize the full dynamics of changes in both liquidity levels and returns during the whole 6-month period after the bankruptcy. Our key variable of interest, *Lehman-HF holdings*$_i$, equals the fraction of shares in stock i that are held in aggregate by all 13F investment advisors with hedge funds that used Lehman as their prime broker. We measure these holdings from the 13F filings in June of 2008, before the onset of the crisis.

Beyond the holdings of the Lehman funds, we also include the share of holdings by *Non-Lehman hedge funds* and by *Other* (*non-hedge-fund*) *institutional investors*. Adding these two variables provides two key benchmarks with which to compare the coefficient of the *Lehman-HF holdings* effect on liquidity. Testing $\gamma^1=0$ boils down to comparing the effect of holdings by Lehman-connected funds with holdings by non-institutional investors (the omitted category). Testing $\gamma^1=\gamma^2$ compares the effect of holdings by Lehman-connected funds with holdings by other hedge funds whose prime broker did not fail, while testing $\gamma^1=\gamma^3$ compares the effect of holdings by Lehman-connected funds with holdings by non-hedge-fund institutional investors.

3.1.1. Liquidity measures (the dependent variables in Eq. (1a))

For the dependent variable in Eq. (1a), we study two simple measures of illiquidity, each built from CRSP daily data: the bid-ask spread divided by the midpoint of the spread (the relative spread), and Amihud's illiquidity index (Amihud, 2002). Amihud's index equals the ratio of the absolute stock return to total dollar volume. The bid-ask spread measures the cost of making small trades. The Amihud index measures the average price impact for all trades made in equilibrium. A low level of this index suggests high liquidity because such stocks can absorb a lot of trading volume without large changes in prices; hence, the index is negatively related to overall liquidity.

For each stock we compute these two measures on each day during the 3 months leading up to Lehman's bankruptcy (the pre-crisis period) and the three months after the September 15 bankruptcy (the post-crisis period). We then average these daily measures for each stock during the two regimes to create the cross-section for Eq. (1). We drop September 1–14, 2008 from both the pre-crisis and post-crisis periods.

3.1.2. Pre-crisis control variables

We control for a set of additional variables that may have been correlated with changes in liquidity across stocks. Each control variable is measured during the pre-crisis period, defined as the three months leading up to the Lehman bankruptcy. These include: (1) the market-model β, to control for stocks' differential exposure to the large market shock that followed Lehman; (2) the liquidity β, to control for stocks' differential exposure to the aggregate liquidity shock that followed Lehman; (3) the pre-crisis liquidity level (the dependent variable in (1a); in (1b), we control for the Amihud index); (4) firm size, measured as both the log of market capitalization and the market-cap-based size rank; (5) industry fixed (and sometimes random) effects, constructed at the three-digit level of disaggregation. These indicators will absorb the effect of the SEC short-sale ban in the fall of 2008, which was targeted at firms in a few industries (e.g., financial firms).

(*footnote continued*)
suggests that the hazard rate also rose for Bear's customers in 2008, but by a much smaller magnitude. This difference likely occurred because Bear Stearns avoided bankruptcy so that its customers' accounts, and thus their ability to trade, did not suffer (see falsification tests below for more evidence on this point).

[10] We reach similar conclusions when we estimate the hazard model using additional fund characteristics as explanatory variables, including the management fee, incentive fee, high-water mark, and Sadka's (2010) liquidity β. We have also estimated a hazard model using quarterly fund observations, and found the Lehman effect in 2008 to be concentrated during the quarter of Lehman's bankruptcy (2008Q3).

Table 4
Distribution of liquidity and equity holdings for hedge funds.

This table describes the distribution of the bid-ask spread (bid-ask/midpoint) and overall price impact (Amihud's illiquidity index) for the three months before and the three months after Lehman Brother's bankruptcy filing on September 15, 2008. The bid-ask spread is the dollar difference between the bid and the ask, divided by the midpoint of the spread. Overall price impact (Amihud) equals the average absolute daily price change divided by dollar volume. Data on stock holdings are taken from the June 2008 13F filings.

	Pre-crisis			*Post-crisis*		
	25th Percentile	Median	75th Percentile	25th Percentile	Median	75th Percentile
Panel A: Distribution of liquidity measures						
Bid-ask spread	0.16%	0.32%	1.11%	0.34%	0.82%	2.98%
Overall price impact (Amihud illiquidity)	0.27%	2.53%	37.87%	0.77%	8.14%	113.30%
Panel B: Distribution of ownership by 13F filers (June 2008)						
Share held by Lehman hedge funds	0.00%	0.00%	0.25%			
Share held by other hedge funds	2.14%	11.52%	23.58%			
Share held by other institutions	7.27%	25.88%	51.42%			
Panel C: Distribution of ownership by Lehman-connected hedge funds						
Number of stocks not held by Lehman funds		3,551				
Number of stocks with less than 1% ownership by Lehman funds		2,400				
Number of stocks with 1% to 5% ownership by Lehman funds		620				
Number of stocks with more than 5% ownership by Lehman funds		240				

3.1.3. Summary statistics

Table 4 reports summary statistics on the distribution for our liquidity measures in the pre-crisis and post-crisis regimes. Both suggest that liquidity fell quite sharply after the Lehman bankruptcy. The median spread rose from 0.3% to 0.8% for the full sample. The Amihud measure also rose sharply. The changes in liquidity are large and are consistent across the whole distribution, meaning that almost all stocks experience liquidity declines.

Before we continue, it is worth emphasizing that we are *not* attempting here to explain the shift in overall market liquidity. In our view, it is difficult or impossible to disentangle the impact of the Lehman failure from the effects of the series of shocks that began around September 15, including the AIG rescue, the run on U.S. money market mutual funds, the widening of credit spreads, contagion into the U.K. and European banking systems, TARP, the extension of deposit insurance and guarantees of bank liabilities, and the rapid and unprecedented creation of new lending facilities by the Federal Reserve.[11] Since our empirical strategy focuses only on cross-sectional variation, the overall effects of these shocks will be absorbed by the intercept. To the extent that the effects of the crisis differed across firms beyond our control variables, we absorb these differences with industry effects.

Table 4 also reports the distribution of our measure of Lehman hedge-fund ownership and overall institutional ownership. We report these from just the pre-crisis period (June 2008) because our empirical strategy holds ownership fixed and asks how its impact on liquidity shifts after the Lehman bankruptcy. Most of the stocks have very low levels of ownership by hedge funds connected to Lehman, but there are more than 650 stocks with ownership above 1.5% for these hedge funds, and 240 have ownership above 5%. Thus, although the Lehman bankruptcy affected a small number of hedge funds (29 of which report 13F), those hedge funds had significant positions ($>5\%$) in enough stocks to give our tests reasonable statistical power.

3.2. Results

Panel A of Table 5 reports the main results. The table contains the models of the bid-ask spread (columns 1 and 2), Amihud's illiquidity measure (columns 3 and 4), and the average daily return between September 15 and September 30, 2008 (columns 5 and 6). We take the log of both liquidity measures so that the effects of the explanatory variables can be interpreted in percentage terms. Because these two measures are always positive by construction, the log transformation does not change the sample size. We report specifications for each of the dependent variables with three-digit level industry effects (both the random effects and the fixed effects model). In all cases, we report robust standard errors clustered by industry grouping.

The regressions show, unambiguously, that liquidity falls more after September 2008 for stocks with high levels of ownership by Lehman's hedge-fund clients, and the differential drop in liquidity comes with a decline in the level of prices. Both the bid-ask spread and the Amihud measure rise more after Lehman's failure for stocks that were held by these hedge funds. The increase in illiquidity is statistically significant across both specifications using the bid-ask spread, and in the random effects models using the Amihud illiquidity measure. The decline in returns is also significant across both models.

Moreover, the sign of Lehman hedge-fund ownership consistently enters with opposite sign of ownership by other institutions (and we can reject the hypothesis that the Lehman hedge-fund ownership effect is equal to the effect of non-Lehman hedge funds at the 5% level in five of six models). In contrast, we *never* find a significant

[11] See Cornett, McNutt, Strahan, and Tehranian (2011) and Ivashina and Scharfstein (2010) for broader discussion of these issues.

Table 5
Regression of liquidity and returns on Lehman-connected hedge fund holdings after the Lehman bankruptcy.

Panels A and B report cross-sectional regressions of the log average effective bid-ask spread ((ask-bid) / midpoint), log of Amihud's illiquidity measure, and the average daily stock return following the Lehman bankruptcy on the pre-crisis market and liquidity betas, pre-crisis liquidity measure, market capitalization, the fraction of the stock held by hedge funds that used Lehman as their prime broker, the fraction of other non-Lehman hedge funds, and the fraction held by all other institutional investors. Average daily stock returns are calculated between 09/15/2008–09/30/2008. We include three-digit SIC industry effects in all models, and standard errors assume clustering at the industry level. A '+' denotes statistical significance at the 10% level, '*' at the 5% level, and '**' at the 1% level.

	Log of bid-ask spread		*Log of Amihud illiquidity*		*Daily stock return (%)*	
Panel A: All Lehman-connected funds						
Pre-crisis market beta	0.05	0.05	0.14	0.11	−0.09	−0.09
	(7.06)**	(5.44)**	(10.17)**	(4.94)**	(5.77)**	(3.17)**
Pre-crisis liquidity beta	0.03	0.02	0.07	0.06	−0.05	−0.04
	(5.07)**	(3.43)**	(5.82)**	(4.01)**	(2.92)**	(2.23)*
Pre-crisis log liquidity level[1]	0.79	0.78	0.85	0.85	−0.02	−0.02
	(75.08)**	(31.95)**	(69.55)**	(16.41)**	(1.70)+	(0.77)
Log(Market capitalization)	0.15	0.15	-0.05	−0.06	−0.22	−0.23
	(10.23)**	(2.63)**	(2.07)*	(2.02)*	(7.23)**	(6.28)**
Market capitalization rank	−1.83	−1.90	−1.08	−1.08	1.36	1.36
	(16.65)**	(4.63)**	(5.67)**	(1.25)	(5.85)**	(2.31)*
Nasdaq dummy	−0.08	−0.04	0.18	0.19	0.08	0.07
	(5.64)**	(2.25)*	(6.21)**	(6.35)**	(2.19)*	(1.33)
(a) Share held by Lehman hedge funds	0.93	0.85	1.18	0.60	−2.33	−2.22
	(3.05)**	(2.90)**	(2.50)*	(1.08)	(3.47)**	(3.12)**
(b) Share held by non-Lehman hedge funds	−0.21	−0.17	−0.35	−0.39	0.18	0.21
	(2.87)**	(1.39)	(2.71)**	(2.30)*	(1.22)	(1.11)
(c) Share held by other institutions	−0.21	−0.17	−0.18	−0.18	0.15	0.17
	(5.03)**	(2.78)**	(2.55)*	(2.08)*	(1.73)+	(1.19)
P-value for *F*-test that: (a)=(b)	0.00	0.00	0.00	0.09	0.00	0.00
P-value for *F*-test that: (a)=(c)	0.00	0.00	0.00	0.15	0.00	0.00
P-value for *F*-test that: (b)=(c)	0.97	0.99	0.32	0.27	0.90	0.90
Observations	5,606	5,606	5,586	5,586	5,507	5,507
R^2 (within industry)	88%	88%	94%	94%	2%	2%
Estimation of industry effects	Random	Fixed	Random	Fixed	Random	Fixed
Panel B: Without press-identified Lehman-connected funds						
Pre-crisis market beta	0.05	0.05	0.13	0.11	−0.09	−0.09
	(6.97)**	(5.26)**	(10.09)**	(4.92)**	(5.68)**	(3.12)**
Pre-crisis liquidity beta	0.03	0.03	0.07	0.06	−0.05	−0.04
	(5.14)**	(3.54)**	(5.87)**	(4.04)**	(2.98)**	(2.27)*
Pre-crisis log liquidity level[1]	0.79	0.78	0.85	0.85	−0.02	−0.03
	(75.37)**	(31.96)**	(69.81)**	(16.51)**	(1.84)+	(0.83)
Log(Market capitalization)	0.15	0.15	−0.06	−0.07	−0.22	−0.23
	(10.08)**	(2.63)**	(2.17)*	(2.10)*	(7.12)**	(6.27)**
Market capitalization rank	−1.81	−1.88	−1.05	−1.06	1.31	1.31
	(16.45)**	(4.68)**	(5.51)**	(1.24)	(5.65)**	(2.27)*
Nasdaq dummy	−0.09	−0.05	0.17	0.18	0.08	0.08
	(5.77)**	(2.37)*	(6.09)**	(6.31)**	(2.31)*	(1.42)
(a) Share held by Lehman hedge funds	1.29	1.18	2.07	1.78	−2.54	−2.82
	(1.90)+	(2.10)*	(2.00)*	(1.51)	(1.64)	(1.73)+
(b) Share held by non-Lehman hedge funds	−0.19	−0.15	−0.33	−0.39	0.11	0.15
	(2.61)**	(1.30)	(2.62)**	(2.35)*	(0.76)	(0.78)
(c) Share held by other institutions	−0.20	−0.17	−0.17	−0.17	0.14	0.17
	(4.91)**	(2.69)**	(2.43)*	(1.94)+	(1.67)+	(1.12)
P-value for *F*-test that: (a)=(b)	0.03	0.03	0.02	0.07	0.09	0.07
P-value for *F*-test that: (a)=(c)	0.03	0.02	0.03	0.11	0.08	0.07
P-value for *F*-test that: (b)=(c)	0.88	0.92	0.35	0.22	0.85	0.96
Observations	5,606	5,606	5,586	5,586	5,507	5,507
R^2 (within industry)	88%	88%	94%	94%	2%	2%
Estimation of industry effects	Random	Fixed	Random	Fixed	Random	Fixed

[1] The liquidity level is the lag of the dependent variables for regressions in columns 1–4; for the stock return regression, we use the lag of the Amihud measure of illiquidity.

difference between the effect of non-Lehman hedge funds and other institutional investors. Our findings suggest that institutional ownership overall mitigated the drop in market liquidity that followed Lehman's collapse, which, as we have mentioned, was followed in quick succession by a series of shocks to the market. Thus, institutions moderated the adverse consequences of these shocks on market liquidity, but Lehman's hedge-fund clients could not contribute to this moderating effect because their positions were frozen.

To understand the magnitude of our results, consider comparing the change in liquidity for a stock with 5%

ownership by Lehman-connected funds to a similar stock with 5% ownership by non-connected hedge funds (i.e., comparing coefficients in rows (a) and (b) from Table 5). The coefficients imply a relative increase in the bid-ask spread of about $5.5\% = 0.05(0.93 - (-0.21))$, from coefficients in column 1 of Table 5; for the Amihud measure, the coefficients imply a relative increase of about $7\% = (0.05(1.18 - (-0.35))$, from coefficients in column 3 of Table 5. While this magnitude may seem small compared to the overall drop in market liquidity (recall Table 4), it is large relative to the cross-sectional variation in changes to market liquidity. For example, the standard deviation (across stocks) of the change in the log of the bid-ask spread was about 0.48, so our coefficient explains more than 10% of this variation. Returns were also affected substantially. Again, comparing stocks with 5% ownership by Lehman funds vs. similar ownership by non-Lehman funds, average daily returns following the Lehman bankruptcy were 0.125% lower $0.05(-2.33-0.18)$, or 1.25% over the 2-week period from September 15, 2008 to the end of the month.

Panel B of Table 5 re-estimates these regressions using only the 17 hedge funds with 13F data that we were able to identify from the TASS database. For this robustness test, we drop the additional 12 hedge funds identified in the Lexis–Nexis search to be sure that a publication bias has not affected our results. The coefficients on the holdings of Lehman-connected funds are slightly larger in magnitude, compared to those reported in Panel A, but with larger standard errors. Nevertheless, we can reject the hypothesis that the Lehman hedge-fund ownership coefficient equals that of the ownership by other institutions at the 10% level or better.

3.3. Two falsification tests

We offer two distinct falsification tests to our main findings. First, we introduce two alternate 'control' groups with which to compare the Lehman-connected hedge funds. In Table 5, the best comparison for the Lehman funds, stocks held by other hedge funds, suggests testing the hypothesis that $\gamma^1 = \gamma^2$ in Eqs. (1a) and (1b)). But perhaps hedge funds choosing another prime broker differ from the Lehman-connected funds along some important unobserved dimension. To rule this out, we create a mirror-image fund for each Lehman fund by matching on style, pre-crisis net asset value (same decile), and returns during 2007 (again, same decile). We then add the share of stock held by these mirror-image funds to our regressions.

In the other 'control group,' rather than find a matching fund, we introduce the share of stock held by all non-Lehman funds that failed, defined as funds whose last reported return to TASS is observed between January and August of 2008. This definition of failure is crude because, as noted earlier, some funds do not report returns to TASS for several months leading up to failure. Hence, our strategy assumes that a fund reporting its last return in, say, April of 2008, actually failed during the turmoil of the fourth quarter.

Table 6 reports these tests. As in Table 5, we consider two liquidity measures and the average return during the 2 weeks following the bankruptcy. In three of three cases (columns 1, 3, and 5), the stocks held by Lehman funds are associated with lower liquidity and lower prices (i.e., more negative returns) relative to the control; that is, the coefficient on Lehman-fund holdings is statistically significantly different (and opposite in sign) from the matched non-Lehman funds at the 5% level (compare rows (a)–(b)).

The coefficients on holdings of non-Lehman failed hedge funds (columns 2, 4, and 6) weakly support the proposition that hedge-fund failure in general harms market liquidity. For the Amihud measure, the coefficient on holdings by non-Lehman failed funds is positive and significantly different from the coefficient on holdings by non-failed funds (column 4, comparing rows (c) and (d)). For returns in column 6, the coefficient on holdings of failed funds is negative, and also significantly different from the coefficient on holdings by non-failed funds. For the bid-ask spread, however, we find no significant difference between holdings by failed vs. non-failed funds (column 2).

In our second falsification test, we compare our results before and after the Lehman debacle with a parallel set of regressions before and after the failure of Bear Stearns. The Bear failure differs fundamentally because bankruptcy did not occur; rather, JPMorgan agreed (with Fed assistance) to purchase all of Bear on March 16, 2008. Since disruptions to customers and counterparties were avoided, we ought not observe differences in liquidity (or returns) comparing stocks held by Bear-connected funds vs. those held by either Lehman-connected funds or other hedge funds. Comparing this test with the analysis in Table 5 highlights differences between a 'bailout' of a large broker-dealer (Bear) vs. a bankruptcy of similar magnitude (Lehman).

To test this idea, we include the share of stock held by Bear's hedge-fund clients and the share of stock held by Lehman's hedge-fund clients prior to Bear's failure. For these tests, the post-crisis period runs from March 16, 2008 through the end of April; the pre-crisis period runs from January 1, 2008 to the end of February, and we measure holdings as of December 2007 from 13F filings. As shown in Table 7, there are no statistically significant differences in liquidity or returns for stocks held by Bear-connected funds vs. those held by Lehman-connected hedge funds; there are also no differences between stocks held by either Bear or Lehman funds from those held by other hedge funds, or by other non-hedge-fund institutional investors. Together, the results of Tables 5 and 7 imply that Lehman clients were only differentially affected when Lehman went bankrupt (providing a nice falsification test), *and* that bankruptcy, not merely failure as in the case of Bear, generated the liquidity effects (since we see none following Bear's demise).

3.4. Persistence of the results

How long does Lehman's bankruptcy affect market liquidity? One might expect other liquidity suppliers, such as other hedge funds, to step in and quickly replace the lost trading capacity after Lehman's failure. On the

Table 6
Regression of liquidity and returns on Lehman-connected hedge fund holdings after the Lehman bankruptcy, with additional comparison groups (first falsification strategy).

This table reports cross-sectional regressions of the log average effective bid-ask spread ((ask-bid)/mid-point), log of Amihud's illiquidity measure, and the average daily stock return following the Lehman bankruptcy on the pre-crisis market and liquidity betas, pre-crisis liquidity measure, market capitalization, the fraction of the stock held by hedge funds that used Lehman as their prime broker, the fraction of non-Lehman funds with similar size, style and past returns, the fraction of non-Lehman hedge funds that failed (defined as funds whose last reported return in TASS was observed between January and August, 2008), the fraction of other non-Lehman hedge funds, and the fraction held by all other institutional investors. Average daily stock returns are calculated between 09/15/2008 and 09/30/2008. We include three-digit SIC industry fixed effects in all models, and standard errors assume clustering at the industry level. A '+' denotes statistical significance at the 10% level, '*' at the 5% level, and '**' at the 1% level.

	Log of bid-ask spread		*Log of Amihud illiquidity*		*Daily stock return (%)*	
Pre-crisis market beta	0.05	0.05	0.11	0.11	−0.09	−0.09
	(5.34)**	(5.38)**	(4.86)**	(4.85)**	(3.12)**	(3.13)**
Pre-crisis liquidity beta	0.02	0.02	0.06	0.06	−0.04	−0.04
	(3.38)**	(3.38)**	(3.88)**	(3.96)**	(2.13)*	(2.14)*
Pre-crisis log liquidity level[1]	0.78	0.78	0.85	0.84	−0.02	−0.02
	(32.01)**	(31.95)**	(16.45)**	(16.17)**	(0.81)	(0.70)
Log(Market capitalization)	0.15	0.15	−0.06	−0.07	−0.23	−0.22
	(2.63)**	(2.66)**	(2.06)*	(2.23)*	(6.26)**	(6.03)**
Market capitalization rank	−1.89	−1.90	−1.07	−1.07	1.35	1.34
	(4.61)**	(4.63)**	(1.25)	(1.23)	(2.29)*	(2.25)*
Nasdaq dummy	−0.04	−0.04	0.19	0.19	0.07	0.07
	(2.17)*	(2.27)*	(6.35)**	(6.32)**	(1.26)	(1.32)
(a) Share held by Lehman hedge funds	0.85	0.86	0.61	0.65	−2.23	−2.27
	(2.92)**	(2.89)**	(1.09)	(1.16)	(3.14)**	(3.21)**
(b) Share held by non-Lehman funds matched on style, size and returns	−0.95	–	−1.33	–	1.66	–
	(2.70)**	–	(2.11)*	–	(2.56)*	–
(c) Share held by non-Lehman failed hedge funds	–	−0.09	–	0.48	–	−0.70
	–	(0.45)	–	(1.65)	–	(1.32)
(d) Share held by all other hedge funds	−0.12	−0.19	−0.32	−0.59	0.11	0.42
	(0.97)	(1.25)	(1.72)+	(3.24)**	(0.55)	(2.47)*
(e) Share held by other institutions	−0.18	−0.17	−0.19	−0.17	0.18	0.16
	(2.90)**	(2.73)**	(2.21)*	(1.82)+	(1.26)	(1.06)
P-value for *F*-test that: (a)=(b)	0.00	–	0.04	–	0.00	–
P-value for *F*-test that: (a)=(c)	–	0.01	–	0.78	–	0.07
P-value for *F*-test that: (a)=(d)	0.01	0.01	0.11	0.04	0.00	0.00
P-value for *F*-test that: (a)=(e)	0.00	0.00	0.15	0.13	0.00	0.00
P-value for *F*-test that: (d)=(e)	0.72	0.92	0.48	0.05	0.79	0.34
P-value for *F*-test that: (b)=(d)	0.03	–	0.14	–	0.03	–
P-value for *F*-test that: (c)=(d)	–	0.68	–	0.00	–	0.03
Observations	5,606	5,606	5,586	5,586	5,507	5,507
R^2 (within industry)	88%	88%	94%	94%	2%	2%
Estimation of industry effects	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

[1] The liquidity level is the lag of the dependent variables for regressions in columns 1–4; for the stock return regression, we use the lag of the Amihud measure of illiquidity.

other hand, recent evidence suggests that several months may go by before market equilibrium returns when external capital market shocks force liquidity providers to reverse course and demand liquidity (Mitchell, Pedersen, and Pulvino, 2007).

To address persistence, we estimate our baseline models during each trading day from July 1, 2008 through March of 2009. We estimate each of our two liquidity models (Eq. (1a)) and the returns model (Eq. (1b)), but, rather than average across all trading days in the fourth quarter of 2008 to build the dependent variable, we now estimate a separate cross-sectional regression for each trading day. That is, we estimate the models using a different dependent variable each day, but using the same set of pre-crisis explanatory variables.[12] So, for example, we run a cross-sectional regression on July 1, 2008 using the bid-ask spread, Amihud, and stock return on that day as the dependent variables, with the same set of pre-crisis variables as regressors for each of these regressions. We then repeat this procedure – changing only the dependent variables – on each day until the end of March 2009. This procedure, similar to the standard Fama-MacBeth procedure employed to test asset pricing models, yields a time-series for each coefficient.[13] The advantage is that we can generate a set of coefficients that will reflect any time-series variation in the relationship as we move further away from the event of Lehman's bankruptcy.

Panels A–C of Fig. 3 characterize the results from our estimates during each day. We plot the 30-day backward-looking moving average (with upper and lower bands representing 99% confidence interval) of the difference

[12] Since we start these cross-sections on July 1, we use pre-crisis liquidity levels using daily averages from April 1 to June 30, 2008.

[13] We have also conducted *t*-tests on the average of the daily coefficients on the share variables over the original event period (e.g. Fama-MacBeth style). The qualitative results are unchanged from the pooled regression results reported in Tables 5 and 6.

Table 7
Regression of liquidity and returns on Lehman- and Bear Stearns-connected hedge fund holdings after the Bear Stearns failure (second falsification strategy).

This table reports cross-sectional regressions of the log average effective bid-ask spread ((ask-bid)/mid-point), log of Amihud's illiquidity measure, and the average daily stock return following the failure of Bear Stearns in March 2008 on the pre-crisis market and liquidity betas, pre-crisis liquidity measure, market capitalization, the fraction of the stock held by hedge funds that used Lehman as their prime broker, the fraction stock held by hedge funds using Bear Stearns as prime broker, the fraction of stock held by all other hedge funds, and the fraction held by all other institutional investors. The dependent variables are calculated as averages from the day after the Bear Stearns purchase by JPMorgan (March 16, 2008) through the end of April. The pre-crisis liquidity levels are calculated from January 1, 2008 to the end of February. The market and liquidity betas are calculated from the beginning of 2005 to the end of 2007. Share holdings are taken from the December, 2007 13F filings. We include three-digit SIC industry fixed effects in all models, and standard errors assume clustering at the industry level. A '+' denotes statistical significance at the 10% level, '*' at the 5% level, and '**' at the 1% level.

	Log of bid-ask spread		*Log of Amihud illiquidity*		*Daily stock return (%)*	
Pre-Bear crisis market beta	0.01	0.00	−0.01	−0.02	0.00	0.00
	(2.48)*	(0.55)	(0.63)	(1.15)	(0.30)	(0.03)
Pre-Bear crisis liquidity beta	0.02	0.02	0.02	0.02	−0.03	−0.03
	(4.59)**	(2.41)*	(2.43)*	(1.84)+	(2.64)**	(2.46)*
Pre-Bear crisis log liquidity level[1]	0.94	0.88	0.92	0.89	0.00	−0.01
	(132.47)**	(51.40)**	(89.23)**	(33.31)**	(0.59)	(0.64)
Log(Market capitalization)	0.07	0.05	0.04	0.00	−0.04	−0.05
	(5.37)**	(5.22)**	(2.29)*	(0.05)	(2.09)*	(2.07)*
Market capitalization rank	−0.77	−0.88	−1.36	−1.37	0.23	0.25
	(8.72)**	(7.78)**	(10.45)**	(4.74)**	(1.64)	(1.77)+
Nasdaq dummy	0.10	0.04	0.21	0.16	0.08	0.06
	(10.73)**	(3.41)**	(10.37)**	(6.50)**	(3.04)**	(1.97)+
(a) Share held by Lehman hedge funds (as of 12/2007)	0.30	0.06	−0.43	−0.36	0.13	−0.04
	(1.08)	(0.22)	(1.02)	(0.71)	(0.24)	(0.07)
(b) Share held by Bear funds (as of 12/2007)	0.02	−0.21	−0.31	−0.50	−0.14	−0.10
	(0.12)	(0.84)	(1.03)	(1.27)	(0.41)	(0.31)
(c) Share held by all other hedge funds (as of 12/2007)	−0.06	−0.20	−0.20	−0.32	0.09	0.07
	(0.98)	(2.52)*	(1.96)+	(2.02)*	(0.94)	(0.72)
(d) Share held by other institutions (as of 12/2007)	0.07	−0.05	−0.06	−0.16	0.15	0.11
	(2.20)*	(1.14)	(1.21)	(2.20)*	(2.52)*	(1.85)+
P-value for *F*-test that: (a)=(b)	0.38	0.51	0.82	0.84	0.67	0.91
P-value for *F*-test that: (a)=(c)	0.21	0.33	0.60	0.94	0.94	0.84
P-value for *F*-test that: (a)=(d)	0.40	0.67	0.39	0.69	0.97	0.78
P-value for *F*-test that: (c)=(d)	0.12	0.01	0.30	0.44	0.65	0.77
Observations	5,717	5,717	5,590	5,590	5,490	5,490
R^2 (within industry)	92%	92%	96%	96%	1%	1%
Estimation of industry effects	Random	Fixed	Random	Fixed	Random	Fixed

[1] The liquidity level is the lag of the dependent variables for regressions in columns 1–4; for the stock return regression, we use the lag of the Amihud measure of illiquidity.

between the coefficient on *Lehman-HF holdings* from the coefficient on the *Matched non-Lehman HF holdings*. The averages are backward-looking; for example, the moving average plotted on September 15, 2008 includes the 30 day prior to and including the Lehman bankruptcy.

Consistent with our pooled regression results, Panels A and B show that stocks held by Lehman hedge funds were consistently associated with lower liquidity during the post-crisis period (but not during the pre-crisis period), relative to stocks held by other similar non-Lehman hedge funds. Moreover, the difference persists, and even grows, through the fall of 2008 and into the beginning of 2009. From that point forward, the effect dissipates, coinciding with a general and gradual restoration of market liquidity. In contrast, returns are negative and significant for the stocks held by Lehman during the first few weeks following the bankruptcy (Panel C). From that point forward, returns are positive for an extended period of time, although we cannot reject that return differences equal zero for the 30-day moving average. However, pooling the returns over the period from the beginning of October to the end of March 2009, the difference in returns for the stocks held by Lehman funds over other stock held by hedge funds is positive (and significant at the 12% level), consistent (weakly) with persistently low liquidity of these stocks requiring a higher expected return to compensate for the additional risk.

Overall, the evidence suggests that a common funding shock to a segment of the hedge-fund market can have a large effect on market illiquidity over an extended period of time. The gradual increase in the liquidity effects is consistent with a liquidity spiral; that is, a downward spiral in which declines in market liquidity feed back into declines in funding liquidity. Having said that, we do not claim to have an empirical strategy to identify the feedbacks between funding and market liquidity beyond what occurred following the initial shock after Lehman's bankruptcy.

3.5. Decomposing illiquidity

We also build two additional measures of liquidity to decompose the Amihud index into price impact related to adverse selection costs, and price impact related to

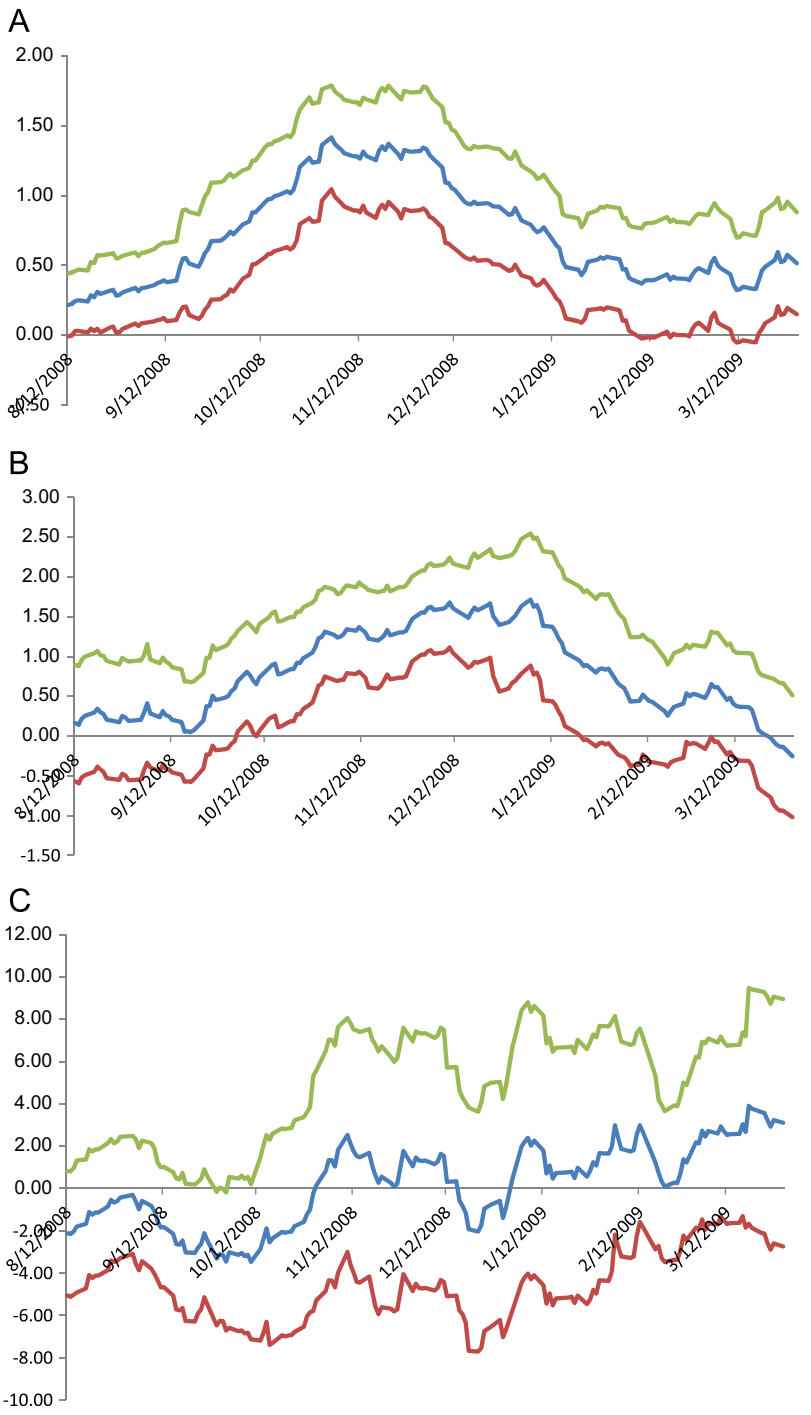

Fig. 3. These figures report a 30-day, backward-looking moving average of the coefficient on the share held by Lehman-connected funds minus the coefficient on the share held by non-Lehman funds matched on style, size and past returns, with 99% confidence bands. Panels A–C show the results from daily cross-sectional regressions when the dependent variable is the Amihud illiquidity measure, bid-ask spread, and return, respectively. Panel A: Cross-sectional regressions with bid-ask spread. Panel B: Cross-sectional regressions with Amihud illiquidity measure. Panel C: Cross-sectional regressions with returns.

order-processing costs. We follow existing studies (Glosten and Harris, 1988; Brennan and Subrahmanyam, 1996; Sadka, 2006) and estimate these liquidity parameters from intraday data using the Trade and Quote (TAQ) database. The literature distinguishes between permanent and transitory components of liquidity. The permanent component reflects changes in the market-maker's valuation of the firm given the privately observed

order flow. This is commonly referred to as the 'adverse selection costs' of trading. The transitory component reflects order-processing costs borne by the market-maker. These costs are transitory because they do not influence the market-maker's private valuation of the security. Most of the permanent part of price impact comes from the variable component, whereas most of the temporary part comes from the fixed component. Thus, we follow Sadka (2006) and focus only on the variable part of the permanent component and the fixed part of the temporary component.

To understand the decomposition, define $m(t)$ as the market-maker's private valuation of the firm given the information contained in past and present order flow at time t. We assume:

$$m(t) = m(t-1) + D(t)[\Psi + \lambda V(t)] + y(t), \tag{2}$$

where $V(t)$ is the order flow, $D(t)$ is an indicator variable that equals one for a buyer-initiated order, and equals negative one for a seller-initiated order. Both $V(t)$ and $D(t)$ are private information observed only by the market-maker. The variable $y(t)$ is the public information available at the end of day t. Eq. (2) also shows that the adjustment to the market-maker's valuation given order flow is assumed to contain both fixed (Ψ) and variable (λ) components.

We follow Sadka (2006) and assume that the market maker's private valuation depends only on the unpredictable variation in order flow. Specifically, in Eq. (2) we replace $D(t)$ and $DV(t)$ with the unexpected components of D and DV, respectively. The unexpected part of signed order flow is defined as the residual to the model

$$DV(t) = \eta_0 + \sum_{j=1}^{5} \eta_j DV(t-j) + \varepsilon_\lambda(t). \tag{3}$$

We also assume that ε_λ is normally distributed conditional on lagged observations of signed order flow.[14] It is easy to show that this implies

$$E_{t-1}[D(t)] = 1 - 2\Phi(-E_{t-1}[DV_t]/\sigma_\varepsilon),$$

where σ_ε denotes the square root of the conditional variance of ε_λ. The unexpected part of the buy/sell indicator is defined as $\varepsilon_\Psi \equiv D(t) - E_{t-1}[D(t)]$. We estimate Eq. (3) every month for each stock and use the fitted values for $E_{t-1}[D(t)]$. An estimate for σ_ε is obtained as the square root of the sample mean squared error from the regression in Eq. (3).

The observed transaction price ($p(t)$) can then be written as,

$$p(t) = m(t) + D(t)[\overline{\Psi} + \overline{\lambda} V(t)]. \tag{4}$$

The transaction price equals the market-maker's private valuation plus the fixed and variable components of order-processing costs. This is the transitory component of liquidity. Taking first differences of Eq. (4) and substituting for $m(t)$ gives

$$\Delta p(t) = \Psi \varepsilon_\Psi(t) + \lambda \varepsilon_\lambda(t) + \overline{\Psi} \Delta D(t) + \overline{\lambda} \Delta DV(t) + y(t), \tag{5}$$

where $DV(t) = D(t)V(t)$ denotes the signed order flow. For each stock, we estimate the four liquidity parameters in Eq. (5) using Ordinary Least Squares (OLS) within each month. We require at least 30 trade observations for the estimation.

The TAQ files are divided into two files: a quotation file and a trade file. The quotation file classifies trades as either buyer or seller-initiated based on the Lee and Ready (1991) algorithm. Specifically, we assume that prices exceed the midpoint of the bid and offer quotes for buyer-initiated trades, and that prices fall below the midpoint of the spread for seller-initiated trades. Trades that occur at the midpoint of the bid and offer are dropped. Lee and Ready (1991) argue that quotes less than 5 seconds old usually reflects information generated by the most recent trades. Therefore, when comparing trades and quotes, we compare the trade price with the most recent bid and offer quotes that have a timestamp of at least five seconds behind the timestamp of the trade.

We also apply the following filters to the trade data: First, we only consider NYSE-listed stocks, although we include trades that do not occur on the NYSE. Second, we keep only those trades that occur between the market opening (9:30 A.M. EST) and 5 minutes after the market closes (4:05 P.M. EST). Third, we keep only regular trades and original trades later corrected, and drop cancelled trades, trades out of sequence, and trades with special conditions.[15] Fourth, we drop trades with negative prices and the first trade after the opening of the exchange. Fifth, we only keep primary market (NYSE) quotes and quotes satisfying various criteria to assure the reasonableness of quote data.[16] Finally, many trades and quotes have the same timestamp for a given security on a given day. In these cases, we only use the final reported trade and quote observation corresponding to each timestamp using the original sequence of observations provided by NYSE TAQ.

In Table 8, we find that the permanent component of price impact for stocks held by Lehman hedge funds actually *declines* significantly, relative to stocks held by others (columns 1 and 2). This suggests that while overall liquidity is dampened because the Lehman funds could not trade after September 15, the information component of trades, which drives the permanent effect of volume on price changes, is reduced. Other liquidity suppliers – market-makers – face an exogenous drop in the likelihood of trading against potentially well-informed hedge funds when Lehman fails, thus lowering the impact of volume on price for these stocks. We find this effect across all four specifications. The last two

[14] Our results are similar if we use ten lags in Eq. (3). Hence, the exact modeling of expected order flow has little impact on our conclusions.

[15] Specifically, we only keep trades if the TAQ correction indicator (Corr) equals zero or one, and only if the sale condition field (Cond) is blank or equals '@' or '*.'

[16] These criteria, used by Sadka (2006), are as follows: quotes in which the bid-ask spread is positive and below $5; quotes in which the bid-ask spread divided by the midpoint of the quoted bid and ask is less than 10% if the midpoint is greater than or equal to $50; and quotes in which the quoted spread is less than 25% for midpoints less than $50.

Table 8
Decomposing the regression of overall price impact on Lehman-connected hedge fund holdings.

This table reports cross-sectional regressions of the variable and fixed components of price impact during the three-months following the Lehman bankruptcy on the pre-crisis market and liquidity betas, the pre-crisis liquidity measure, market capitalization, the fraction of the stock held by hedge funds that used Lehman as their prime broker, the fraction of other non-Lehman hedge funds, and the fraction held by all other institutional investors. We include three-digit SIC industry effects in all models, and standard errors assume clustering at the industry level. A '+' denotes statistical significance at the 10% level, '*' at the 5% level, and '**' at the 1% level.

Impact	*Permanent-variable (information) price impact*		*Temporary-fixed (non-information) price impact*	
Pre-crisis market beta	−0.09	−0.17	0.00	0.01
	(0.56)	(0.90)	(2.04)*	(3.38)**
Pre-crisis liquidity beta	0.32	0.36	0.00	0.00
	(2.03)*	(1.89)+	(1.72)+	(1.49)
Pre-crisis log liquidity level[1]	0.25	0.24	0.80	0.79
	(6.26)**	(6.62)**	(12.49)**	(12.74)**
Log(Market capitalization)	−0.25	−0.16	0.00	0.00
	(1.51)	(1.19)	(3.17)***	(2.91)**
Market capitalization rank	−9.21	−9.77	−0.07	−0.06
	(4.65)**	(6.65)**	(5.11)**	(5.89)**
(a) Share held by Lehman hedge funds	−11.51	−13.24	0.03	0.04
	(2.84)**	(3.39)**	(1.09)	(1.43)
(b) Share held by non-Lehman hedge funds	1.64	−0.03	−0.04	−0.02
	(0.91)	(0.02)	(5.96)**	(3.70)**
(c) Share held by other institutions	−2.24	−1.86	−0.01	−0.00
	(2.59)**	(1.78)+	(2.91)**	(0.37)
P-value for *F*-test that: (a)=(b)	0.00	0.00	0.02	0.04
P-value for *F*-test that: (a)=(c)	0.03	0.01	0.15	0.16
P-value for *F*-test that: (b)=(c)	0.12	0.46	0.01	0.02
Dependent variable distribution:				
25th Percentile	−0.058		0.015	
Median	2.280		0.025	
75th Percentile	5.564		0.051	
Observations	2,044	2,044	2,041	2,041
R^2 (within industry)	22%	22%	51%	51%
Estimation of Industry Effects	Random	Fixed	Random	Fixed

[1] The liquidity level is the lag of the dependent variable.

columns in Table 8 suggest that the temporary component of price impact increases more for stocks held by Lehman funds. The coefficient is not statistically significantly different from zero, but it is significantly different from the coefficient on other institutions. Thus, while hedge funds supply liquidity overall, their presence in the market raises the probability of private information and thus increases the adverse selection component of trading costs.

3.6. Cross-sectional difference in the effects of funding shocks

In our last set of tests, we re-estimate the models for stocks that had above-median vs. below-median levels of liquidity in the pre-crisis period. Brunnermeier and Pedersen (2009) suggest that links from funding liquidity to market liquidity ought to be greatest for relatively illiquid assets, so we ought to observe a greater impact on market liquidity of the Lehman bankruptcy for those stocks that were more illiquid prior to the shock. This is indeed what we find (Table 9). For stocks with below-median initial liquidity, we estimate large and significant effects of the Lehman bankruptcy; for the above-median liquidity stocks, however, the effects are smaller and/or not statistically significant. In terms of magnitudes, an increase in ownership from zero to 5% by the Lehman-connected funds would come with a 6% increase in the bid-ask spread and a 12% increase in the Amihud illiquidity index.

4. Conclusions

Shocks to fundamentals that reduce financial institutions' wealth (capital) may potentially set off a downward spiral in both asset prices and market liquidity by tightening constraints on their ability to trade (Brunnermeier and Pedersen, 2009). This idea helps explain why market liquidity in U.S. equities dried up spectacularly after the failure of Lehman Brothers on September 15, 2008, and why this event was followed in close succession by a cascade of shocks into both credit markets and stock markets across the world. Tracing a causal connection from the funding liquidity of traders to the market liquidity of their positions is difficult, however, for at least two reasons. First, since illiquid assets make bad collateral, the models themselves imply a two-way feedback between market liquidity and funding liquidity. Second, traders have incentives to tilt their positions toward less liquid markets (to profit from temporary deviations between prices and fundamentals) and to move in and out of positions as liquidity changes (as was done by LTCM).

In this paper, we avoid these endogeneity problems and offer direct evidence that declines in funding liquidity *caused* declines in market liquidity. We exploit the Lehman bankruptcy as a plausibly exogenous negative shock to funding liquidity. Hedge funds that used Lehman as their prime broker faced a sudden loss of funding

Table 9
Regression of liquidity on Lehman-connected hedge fund holdings, above- vs. below-median pre-crisis liquidity.

This table reports cross-sectional regressions of each of the four liquidity measures during the three-months following the Lehman bankruptcy on the pre-crisis market and liquidity betas, the pre-crisis liquidity measure, market capitalization, the fraction of the stock held by hedge funds that used Lehman as their prime broker, the fraction held by other non-Lehman hedge funds, and the fraction held by all other institutional investors. Each of the regressions is run separately for firms above and below the initial median level of liquidity measured in the pre-crisis months. A '+' denotes statistical significance at the 10% level, '*' at the 5% level, and '**' at the 1% level.

	Log of bid-ask spread		*Log of Amihud illiquidity*		*Permanent-variable (information) price impact*		*Temporary-fixed (non-information) price impact*	
	High liquidity$_0$	*Low liquidity*$_0$	*High liquidity*$_0$	*Low liquidity*$_0$	*High liquidity*$_0$	*Low liquidity*$_0$	*High liquidity*$_0$	*Low liquidity*$_0$
Pre-crisis market beta	0.06	0.03	0.16	0.05	0.41	−0.54	0.00	0.01
	(4.07)**	(3.02)**	(7.61)**	(2.27)*	(2.10)*	(1.73)+	(2.09)*	(3.40)**
Pre-crisis liquidity beta	0.04	0.01	0.07	0.04	0.09	0.39	0.00	0.00
	(3.45)**	(1.01)	(3.30)**	(1.91)+	(0.51)	(1.29)	(2.61)**	(0.65)
Pre-crisis log liquidity level[1]	0.77	0.70	1.03	0.75	0.02	0.20	0.57	0.75
	(12.42)**	(27.84)**	(24.44)**	(25.16)**	(0.30)	(3.96)**	(4.16)**	(10.56)**
Log(Market capitalization)	0.09	0.08	−0.03	0.06	−0.39	−0.44	0.00	0.00
	(2.44)*	(1.20)	(1.01)	(1.07)	(2.23)*	(0.67)	(1.27)	(0.73)
Market capitalization rank	−1.20	−1.61	0.21	−2.62	−5.62	−8.16	−0.02	−0.08
	(7.77)**	(3.32)**	(0.40)	(3.25)**	(3.20)**	(1.98)*	(3.79)**	(1.96)+
Nasdaq dummy	−0.15	0.06	0.00	0.22	–	–	–	–
	(5.81)**	(2.17)*	(0.07)	(3.91)**	–	–	–	–
(a) Share held by Lehman hedge funds	0.67	1.19	−0.42	2.01	−4.75	−18.91	0.01	0.14
	(1.98)*	(2.35)*	(0.64)	(2.89)**	(1.07)	(3.02)**	(0.78)	(2.05)*
(b) Share held by non-Lehman hedge funds	−0.08	−0.12	0.20	−0.58	−0.24	−1.32	−0.01	−0.06
	(0.70)	(0.73)	(1.14)	(2.74)**	(0.17)	(0.37)	(2.76)**	(3.67)**
(c) Share held by other institutions	−0.19	0.04	−0.06	−0.19	−0.18	−4.32	−0.01	0.01
	(3.68)**	(0.52)	(0.78)	(1.53)	(0.23)	(2.39)*	(4.32)**	(0.45)
P-value for *F*-test that: (a)=(b)	0.04	0.01	0.38	0.00	0.32	0.02	0.18	0.01
P-value for *F*-test that: (a)=(c)	0.01	0.02	0.60	0.00	0.32	0.03	0.17	0.06
P-value for *F*-test that: (b)=(c)	0.42	0.44	0.19	0.16	0.98	0.50	0.83	0.01
Observations	2,679	2,927	2,643	2,943	1,019	1,025	1,022	1,019
R^2 (within industry)	47%	75%	88%	83%	14%	17%	17%	43%
Estimation of industry effects	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed	Fixed

[1] The liquidity level is the lag of the dependent variable.

liquidity. Some funds had all of their positions frozen after the bankruptcy filing. We show first that hedge funds using Lehman as prime broker were more likely to fail after September, conditional on their past returns and investment flows. This result supports our key identification assumption that Lehman's demise harmed its hedge-fund clients. Second, we show that the market liquidity of stocks held by Lehman's hedge-fund clients fell more during the crisis than otherwise similar stocks not held by these funds. Prices of stocks held by Lehman-connected funds fell more than otherwise similar stocks immediately after the bankruptcy, and then had higher returns for several months, presumably compensating investors for their greater liquidity risk over this period.

Our findings persist and even grow into the beginning of 2009. Amplification of shocks over time is consistent with models of liquidity spirals, whereby an initial decline in funding liquidity can be worsened by reduced market liquidity. We do not claim, however, to have a clear identification strategy to trace out the dynamics of such spirals beyond the initial shock following the Lehman bankruptcy. Ownership by hedge funds and other institutional investors as a whole seemed to have mitigated the declines in liquidity in the fall of 2008. Our findings suggest that the bankruptcy of Lehman Brothers prevented some hedge-fund investors from playing this stabilizing role.

References

Aitken, J., Singh, M., 2009. Deleveraging after Lehman: evidence from reduced rehypothecation. International Monetary Fund Working Paper No. 09/42.

Acharya, V., Pedersen, L., 2005. Asset pricing with liquidity risk. Journal of Financial Economics 77, 375–410.

Amihud, Y., 2002. Illiquidity and stock returns: cross-section and time-series effects. Journal of Financial Markets 5, 31–56.

Amihud, Y., Mendelson, H., 1986. Asset pricing and the bid-ask spread. Journal of Financial Economics 17, 223–249.

Aragon, G.O., 2007. Share restrictions and asset pricing: evidence from the hedge fund industry. Journal of Financial Economics 83, 33–58.

Brennan, M.J., Subrahmanyam, A., 1996. Market microstructure and asset pricing: on the compensation for illiquidity in stock returns. Journal of Financial Economics 41, 441–464.

Brunnermeier, M., Pedersen, L., 2009. Market liquidity and funding liquidity. Review of Financial Studies 22, 2201–2238.

Brunnermeier, M., Nagel, S., 2004. Hedge funds and the technology bubble. Journal of Finance 59, 2013–2040.

Chordia, T., Roll, R., Subrahmanyam, A., 2001. Market liquidity and trading activity. Journal of Finance 45, 501–530.

Comerton-Forde, C., Hendershott, T., Jones, T.M., Moulton, P.C., Seasholes, M.S., 2010. Time variation in liquidity: the role of market maker inventories and revenues. Journal of Finance 65, 295–331.

Cornett, M., McNutt, J., Strahan, P.E., Tehranian, H., 2011. Liquidity risk management and credit supply in the financial crisis. Journal of Financial Economics 101, 297–312.

Ebers, N., 2008. Changing relationships. Financial Times Mandate. 〈http://www.ftmandate.com/news/fullstory.php/aid/1909/Changing_relationships.html〉.

Fernando, C.S., May, A.D., Megginson, W.L. The value of investment banking relationships: evidence from the collapse of Lehman Brothers. Journal of Finance, forthcoming.

Getmansky, M., Lo, A.W., Mei, S.X., 2004. Sifting through the wreckage: lessons from recent hedge fund liquidations. Journal of Investment Management 2, 6–38.

Glosten, L.R., Harris, L.E., 1988. Estimating the components of the bid/ask spread. Journal of Financial Economics 21, 123–142.

Griffin, J.M., Xu, J., 2009. How smart are the smart guys? A unique view from hedge fund stock holdings. Review of Financial Studies 22, 2531–2570.

Ivashina, V., Scharfstein, D.S., 2010. Bank lending during the financial crisis of 2008. Journal of Financial Economics 97, 319–338.

Kovner, A., forthcoming. Do underwriters matter? Evidence from the near loss of an equity underwriter. Journal of Financial Intermediation, forthcoming.

Lee, C., Ready, M.J., 1991. Inferring trade direction from intraday data. Journal of Finance 46, 733–746.

Mitchell, M., Pedersen, L.H., Pulvino, T., 2007. Slow moving capital. American Economic Review 97, 215–220.

Pastor, L., Stambaugh, R., 2003. Liquidity risk and expected stock returns. Journal of Political Economy 111, 642–685.

Sadka, R., 2006. Momentum and post-earnings-announcement drift: the role of liquidity risk. Journal of Financial Economics 80, 309–349.

Sadka, R., 2010. Liquidity risk and the cross-section of hedge-fund returns. Journal of Financial Economics 98, 54–71.