FUNDING LIQUIDITY RISK OF FUNDS OF HEDGE FUNDS: EVIDENCE FROM THEIR HOLDINGS

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ABSTRACT

We examine the funding liquidity risk of funds of hedge funds (FoFs) by proposing a new measure, *illiquidity gap*, which captures the mismatch between the liquidity of a FoF's portfolio and the liquidity offered to its own investors. We find that hedge funds that are exposed to the flow-driven sales of FoFs, especially those with higher illiquidity gaps, subsequently exhibit lower abnormal returns. We show that FoFs with greater illiquidity gaps are less likely to be able to access star hedge funds, perform worse during market crises, and have a greater exposure to runs as evident from a higher sensitivity of investor flows to poor performance.

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1. Introduction

Funds of hedge funds (FoFs) may be subject to significant funding liquidity risk when faced with unanticipated and massive investor redemptions. This risk is magnified when there is an imperfect match between the liquidity of FoFs' assets (i.e., hedge fund investments) and the liquidity of FoFs' liabilities (i.e., investor redemptions).[1] Such mismatches can also occur in other institutions but the extent of mismatches is somewhat bounded due to the restrictions placed on the liquidity of assets and liabilities of regulated entities such as commercial banks and mutual funds.[2] In contrast, the largely unregulated hedge fund industry offers a unique setting where funds have greater latitude to choose the liquidity of both assets and liabilities. At the same time, limited regulation also makes it challenging to study these issues as information on the liquidity of assets and liabilities of hedge funds is typically not available. We overcome this challenge by using the reported assets and liabilities of a sample of registered FoFs to study the effects of the liquidity mismatches on the transmission of liquidity shocks among the constituent hedge funds of FoFs, and the performance and portfolio choice of FoFs.

Specifically, we address the following questions in this study. Do hedge funds in FoF portfolios suffer when FoFs face funding liquidity shocks in the form of extreme investor redemptions? Is this especially the case for hedge funds that have fewer redemption restrictions and are held by FoFs with greater liquidity mismatches, and are therefore more exposed to FoF liquidity shocks? Furthermore, what are the consequences

[1] FoFs are major investors in hedge funds and held 20% of the industry's $2.2 trillion in assets at the end of 2013 (Source: BarclayHedge).

[2] For example, mutual funds typically need to provide daily investor redemptions and are prohibited from investing more than 15% of their assets in illiquid securities.

of the liquidity mismatches for FoF investors? For example, do liquidity mismatches limit a FoF's access to best performing ("star") hedge funds who are likely to have greater access to other sources of capital and therefore may not want to bear the liquidity spillover risk resulting from FoF redemptions? In addition, are FoFs with greater liquidity mismatches associated with better performance during normal times but worse performance during crisis periods, an indication of greater funding liquidity risk? Finally, are FoF's with greater liquidity mismatches more vulnerable to investor runs, as would be evident by a greater sensitivity of investor flows to poor performance?

We use two main data sources for our empirical analysis. First, we hand-collect N-Q, N-CSR, and N-CSRS filings to extract the mandatorily disclosed quarterly portfolio holdings (i.e., positions in underlying hedge funds) from all registered FoFs over the 2004–2011 period. These data also contain the liquidity terms of underlying hedge funds, which state the redemption frequency of the hedge funds. Second, we obtain similar liquidity terms for the FoFs from their registration statements (regulatory filing N-2). Together, these two data sources allow us to construct our measure of liquidity mismatches in FoFs, *illiquidity gap*, which is calculated as the difference between the liquidity terms of the FoF's underlying hedge funds (assets) and the FoF's themselves (liabilities).[3] We observe significant variation in the degree of illiquidity gap, with an interquartile range from –59 days (25th percentile) to 17 days (75th percentile), and where the negative illiquidity gap corresponds to a liquidity cushion.

[3] Our results are qualitatively unchanged when we use an alternative measure of illiquidity gap defined as the percentage of a FoF's assets with a longer redemption frequency than that is applied to its own investors. The sample correlation between the two illiquidity gap measures is 56%.

Our empirical analysis uncovers several new results that shed light on the funding liquidity risk in FoFs and its implications for FoF investors and the hedge funds held by FoFs. Our first finding relates to the distressed selling decisions of FoFs that experience large investor redemptions. We observe that FoFs respond to redemptions by partially or completely liquidating their investments in hedge funds. Specifically, FoFs experiencing bottom-decile flows reduce their position in 28% of hedge funds held during the quarter, compared to only 8% among FoFs in the top decile of flows. We also find that FoFs typically hold both liquid (i.e., those that allow frequent redemptions) and illiquid hedge funds, and that liquidity strongly influences a FoF's selling decisions. In particular, FoFs experiencing outflows are more likely to reduce their investment in liquid funds compared to illiquid funds. Interestingly, FoFs with extreme outflows are more likely to sell their best-performing liquid funds, as compared to their worst-performing illiquid funds. For example, in case of the FoFs with outflows in the top five percentile across all FoFs, we observe that about 70% of the liquid best-performing hedge funds in the FoF portfolios are sold compared to only 33% of the illiquid worst-performing hedge funds.

Our second finding relates to the post-sale performance of the underlying hedge funds involved in flow-driven sales by FoFs. Using style-adjusted returns to benchmark fund performance, we uncover cumulative underperformance of 3.28% over four quarters among sold hedge funds with low redemption restrictions. These adverse effects are more pronounced for these liquid hedge funds that are sold by FoFs with greater illiquidity gaps. The intuition behind this result is that FoFs with larger illiquidity gaps have fewer liquid funds to absorb the liquidity needs of FoF investors and, in the event of outflows, these liquid funds would experience greater selling pressure by FoFs. Furthermore, we

find no evidence of abnormal performance following the flow-driven sales of funds that allow redemption at a much lower frequency (illiquid funds), and therefore who are better equipped to avoid a disorderly liquidation of their assets. Together, these results underscore the significant costs of providing liquidity in response to the flow-driven sales by FoFs, and such costs being mainly borne by liquid hedge funds, especially those held by FoFs with larger asset-liability liquidity mismatches.

Our next result relates to examining whether a FoF's liquidity mismatch impacts its access to the best performing ("star") hedge funds. Star funds can plausibly attract capital from several potential investors. Therefore, we hypothesize that liquid star hedge funds should be reluctant to accept investments from FoFs with higher illiquidity gaps, because they may be subjected to liquidity spillover risk, i.e., being sold during times of crisis if FoFs are unable to redeem from illiquid and poorly performing funds. Consistent with this hypothesis, we find that an increase in illiquidity gap of 100 days is associated with a 0.3% lower FoF investment in star liquid hedge funds as a proportion of all liquid funds held by the FoF. This figure corresponds to 27% of the average investment of 1.1% in star liquid hedge funds. Our hypothesis is further supported by contrasting evidence from star illiquid hedge funds that do not exhibit reluctance to accept capital from FoFs that have high illiquidity gaps.

Our next result relates to examining whether FoFs' liquidity mismatches capture their liquidity risk, which would predict differential performance across normal and crisis periods. We recognize the endogenous nature of the illiquidity gap and implement a two-stage least squares (2SLS) approach. Specifically, in the first stage we model the determinants of a FoF's illiquidity gap and use family size at FoF's inception as an

instrumental variable (see Teo, 2011 and Ramadorai, 2012). We find that family size to be positively related to illiquidity gap, consistent with the notion that funds operated by larger families have lower exposures to funding liquidity risk, and can therefore maintain larger illiquidity gaps. Our second stage results show that higher illiquidity gap is indicative of greater funding liquidity risk in FoFs. In particular, during normal times, a higher illiquidity gap bolsters FoFs' quarterly returns by about 1.6% per one standard deviation increase in illiquidity gap. However, this relation turns negative during crisis periods when a similar increase in illiquidity gap is associated with a 2.1% *decrease* in quarterly returns.

The worse performance of FoFs with higher illiquidity gaps during crises can be related to the strategic complementarities among investors. The theoretical underpinnings of this phenomenon can be found in the context of mutual funds (Chen, Goldstein, and Jiang, 2010) and hedge funds (Liu and Mello, 2011). In our setting, this situation arises in the case of FoFs with high illiquidity gaps, because investors can anticipate both a lack of available liquidity and the adverse effects of distressed sales by FoFs. This can, in turn, subject the FoFs to runs where some investors pre-emptively withdraw their capital before others. Consistent with the notion that such runs can amplify the funding liquidity risk of FoFs, we find that illiquidity gaps in FoFs are associated with greater sensitivity of investor flows to poor past performance.

In proposing and constructing an illiquidity gap measure for FoFs, we contribute to the literature that studies liquidity mismatches in other financial institutions, like commercial banks (see, e.g., Brunnermeier, Gorton, and Krishnamurthy (2011) and Bai, Krishnamurthy, and Weymuller (2014)). We believe our setting is unique for at least two

reasons. First, the liquidity of assets (underlying funds) and liabilities (FoF itself) are measured in the same units – that is, the permitted frequency of investor redemptions. Second, the information about redemption terms is mandatorily reported and directly observable from the regulatory filings. This helps us avoid the empirical challenge of estimating other measures of an asset's market liquidity, such as the price impact of trading. We also show that liquidity mismatches can have far-reaching effects on the performance of underlying hedge funds as well as FoFs, in addition to FoFs' ability to access the very best hedge funds.

Our analysis also contributes to the literature on the portfolio decisions of distressed investors and the cost of distress sales. Prior studies find that distressed investors have a preference for selling liquid assets and that distressed selling can be costly because it can create downward price pressure.[4] Our study provides evidence on the costs of distressed sales by FoFs by showing that hedge funds underperform after being sold, and that exposure to liquidity mismatches can magnify these effects.

Our findings also shed light on stylized patterns in hedge fund returns documented in prior literature. In particular, earlier studies report higher returns for funds that restrict the liquidity of their investors.[5] Based on our evidence, at least part of this "illiquidity premium" can be explained by liquid funds being adversely affected by the

[4] Evidence of institutional price pressure is found in U.S. equity markets (Coval and Stafford, 2007; Hau and Lai, 2012; Tang, 2013; Aragon and Strahan, 2012; Kang, Kondor, and Sadka, 2014), bond markets (Manconi, Masssa, and Yasuda, 2012), and international equity markets (Jotikasthira, Lundblad, and Ramadorai, 2012). Aragon, Martin, and Shi (2014) find that illiquid hedge funds profit from the distressed selling of liquid funds. Diamond and Dybvig (1983), Shleifer and Vishny (1992), and Brunnermeier and Pedersen (2009) present theoretical predictions on the effects of financial distress on asset values.

[5] Evidence that hedge fund returns are positively related to redemption restrictions is reported by Liang (1999), Aragon (2007), Agarwal, Daniel, and Naik (2009), among others.

distressed selling of fund investors. Prior studies also find that exposure to liquidity risk – the covariance of fund returns to changes in market liquidity – is an important determinant of hedge fund performance.[6] We find that liquidity risk in FoFs can result from liquidity mismatches between its assets and liabilities, because illiquidity gaps are associated with worse performance during market crises.

Finally, we build on recent work of Aiken, Clifford, and Ellis (2013, 2014a, 2014b) that studies the portfolio holdings of registered FoFs. Aiken, Clifford, and Ellis (2014a) find that many hedge funds use their discretion to suspend investor redemptions during a crisis. Our findings suggest that the decision of a fund in a FoF's portfolio to become illiquid (e.g., by raising the gates) may force liquid funds held in the same portfolio to bear the costs of providing liquidity to the FoF. Aiken, Clifford, and Ellis (2014b) report that hedge funds that are sold by FoFs experience worse post-sale performance. By focusing on FoFs experiencing outflows, especially those with higher liquidity mismatches, we show that the worse performance of funds sold by FoFs is partly attributable to investor redemptions from FoFs.

The remainder of our paper is organized as follows. Section 2 describes the data sources and construction of our sample, as well as basic summary statistics. Section 3 investigates the selling decisions of FoFs. Sections 4 and 5 analyze the impact of asset-liability liquidity mismatches in FoFs on the underlying hedge funds and on FoFs, respectively. Section 6 concludes.

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[6] Sadka (2010) and Teo (2011) study liquidity risk in hedge fund returns. Cao, Chen, Liang, and Lo (2013) argue that hedge funds can time their exposures to liquidity risk. Lou and Sadka (2011) find that liquid stocks underperform illiquid stocks during the recent financial crisis, because liquid stocks can have high liquidity risk.

2. Data and summary statistics

2.1. Identification of registered funds of hedge funds (FoFs)

We collect the quarterly portfolio holdings of FoFs that register with the U.S. Securities and Exchange Commission (SEC) as closed-end funds under the Investment Company Act of 1940. The main benefit to FoFs from registration is a greater access to investors, including retirement plan investors, and the ability to market and advertise the fund (Seward and Kissel, 2013).[7] However, registration triggers certain disclosure requirements, including the public filing of a registration statement and portfolio holdings.

Our procedure for identifying registered FoFs is similar to Aiken, Clifford, and Ellis (2013). First, we identify all closed-end funds that do not have a closing price and mention "0.00" in their response to question #76 in NSAR filings. This helps us separate traditional closed-end funds from registered FoFs, whose shares are typically not exchange-traded. This yields us a sample of 314 funds that can potentially be identified as registered FoFs. We then collect data on the holdings of these funds to determine if the underlying holdings are funds or securities (e.g., stocks, bonds, etc.) to distinguish between closed-end mutual funds (which should hold securities) and closed-end fund of funds (which should hold mutual funds or hedge funds). This step allows us to remove 127 closed-end funds from 314 funds to leave us with 187 FoFs. We further filter the

[7] Source: http://www.sewkis.com/files/Event/d56557f0-3126-4b90-8bc8-87378e8d5f03/Presentation/EventAttachment/e9d69144-a761-472e-87fb-8cbd48dc8c8f/RegFunds.PPT.

FoFs that invest in mutual funds and that are registered but never raise any capital, which leaves us with a sample of 144 FoFs. Next, we remove the duplicate entries for master-feeder funds, which brings down the sample size to 91 funds. Finally, we remove filings with missing values on the value and cost fields of all their underlying holdings. This selection process yields us our final sample of 79 FoFs. Although our sample is relatively small compared to all FoFs (i.e., registered plus non-registered FoFs), it represents the universe of registered FoFs and is fairly representative of the performance of non-registered FoFs (Aiken, Clifford, and Ellis, 2013).

2.2 Data sources

We use two main databases in our study. First, we hand collect the quarterly portfolio holdings (i.e., positions in underlying hedge funds) of all registered FoFs from N-Q, N-CSR, and N-CSRS regulatory filings from 2004Q3 (when FoFs started disclosing their holdings on a quarterly basis) until 2011Q4. These regulatory filings contain the market value, the cost, the redemption frequency (i.e., liquidity), and the investment style of the underlying hedge funds, along with the net asset values of FoFs. These disclosures provide a window into the portfolio decisions of FoFs. Second, we obtain the promised liquidity terms (i.e., redemption frequency) of each FoF from its registration statement form (N-2 and N-2 amendments).[8] Finally, to augment any missing information from the regulatory filings in the two main data sources, we obtain performance and liquidity

[8] To check whether the actual redemption frequency differs from what is promised in the N-2 filings, we manually collect the SC-TO and SC-TO/A filings for the FoFs in our sample over 2004-2011, which are tender offers made by the FoFs to repurchase shares from their investors (and, hence, offer redemptions). By counting the number of tender offers made by the FoFs in these filings, we compute the actual redemption frequency and compare it with the promised redemption terms contained in the matched sample of N-2 filings. We find that the redemption frequency is not economically different between the two sources (the median of the difference is only 0.01 redemptions per year).

terms of the FoFs and their underlying hedge funds from a union of four commercial hedge fund databases (Eurekahedge, Hedge Fund Research (HFR), Lipper TASS, and Morningstar).

2.3. Variable construction and summary statistics

Panel A of Table I reports the summary statistics on the characteristics of FoF portfolios. The average (median) FoF assets under management (AUM) during the sample period is $328 million ($125 million). The average (median) number of hedge funds in a FoF portfolio is 27 (23). The average (median) market value of an underlying hedge fund position is about $11 million ($5 million), which is about 6% (4%) of the total assets in a FoF. Our sample characteristics are comparable to those of prior studies using similar data.[9]

Panel B reports the range and standard deviation of the redemption restriction of the constituent hedge funds in a FoF portfolio. We define *redemption restriction* as the inverse of a constituent hedge fund's redemption frequency.[10] For example, if a hedge fund permits its investors to redeem shares semiannually, its redemption restriction is equal to 365/2 or 182.5 days. The average range and standard deviation of hedge fund redemption restriction in a FoF portfolio are 330.91 and 104.49 days, respectively. These

[9] For example, Aiken, Clifford, and Ellis (2013) document a sample mean (median) AUM of $273 million ($113 million) and a sample mean (median) number of underlying hedge fund positions of 23 (21).

[10] For robustness, in addition to our primary measure of redemption restriction, we also use the sum of three liquidity variables – lockup period, notice period, and the redemption restriction – as an alternative measure. Since lockup and notice periods of hedge funds are not reported in the regulatory filings, this alternative measure is only available for a subset of the funds that report to the commercial databases.

summary statistics of the redemption restriction suggest that there is significant cross-sectional variation in the liquidity of the constituent hedge funds in a FoF portfolio.[11]

Finally, we define a FoF's *illiquidity gap* as the difference between its asset illiquidity and its liability illiquidity. Asset illiquidity is the value-weighted average of the redemption restrictions of underlying hedge funds held by a FoF, while liability illiquidity is the redemption restriction that the FoF applies to its own investors. Our calculations of asset illiquidity incorporate a FoF's cash position by assigning cash a redemption restriction of zero days. A lower illiquidity gap indicates a greater amount of available asset liquidity (i.e., less illiquidity) relative to that offered to FoF investors. Panel C shows that, on average, a FoF investor faces a greater redemption restriction (141 days) compared to that of hedge funds held in the FoF portfolio (117 days). While this indicates that FoFs have a 24–day "liquidity cushion", on average, we observe that the illiquidity gap can vary significantly as it has an interquartile range of 76 days (–58.89 to 17.13 days).

3. Selling decisions of funds of hedge funds

3.1 Do outflows from FoFs drive their decision to sell underlying hedge funds?

We start our analysis by calculating the quarterly returns of constituent hedge funds in FoF portfolios as in Aiken, Clifford, and Ellis (2013):

$$Return_{i,t} = \frac{Value_{i,t} - \Delta Cost_{i,t-1\ to\ t}}{Value_{i,t-1}} \quad (1)$$

[11] If the redemption frequency of an underlying hedge fund in a quarter is not reported in a quarterly filing, we use the values reported by other FoFs that hold the same hedge fund in the same quarter. We further replace the missing redemption frequency using reported values in the nearest quarter available. Finally, we use the redemption frequency reported in the commercial databases to fill in the remaining missing values.

where $Return_{i,t}$ is the quarterly return of the constituent hedge fund *i* during quarter *t*, $Value_{i,t}$ is the value of the constituent hedge fund *i* held by a FoF at the end of quarter *t*, and $\Delta Cost_{i,t-1\ to\ t}$ is the change in cost of the constituent hedge fund *i* from quarter end *t-1* to quarter end *t*. Both *Value* and *Cost* are directly observable from the quarterly regulatory filings. When the same hedge fund is held by multiple FoFs in the same quarter, our computation may produce different hedge fund returns using different FoF filings. In such cases, we use the average of the returns across the filings. For the hedge fund returns that cannot be computed due to either missing *Cost* or *Value*, we use the reported returns in the commercial databases, if available.

Next we calculate the quarterly net flows of a FoF as follows:

$$Flow_{j,t} = \frac{AUM_{j,t} - AUM_{j,t-1} * (Return_{j,t} + 1)}{AUM_{j,t-1}} \quad (2)$$

where $Flow_{j,t}$ is the net flow to FoF *j* during quarter *t* and $AUM_{j,t}$ is the assets of FoF *j* at the end of quarter *t*. $Return_{j,t}$ is the return of FoF *j* during quarter *t* and is calculated as the value-weighted average return of the underlying holdings of FoF *j* in quarter *t*. In addition to hedge fund holdings, FoFs may also hold cash. We calculate the amount of cash as the difference between the net assets of a FoF and the aggregate market value of the underlying hedge funds. When computing the returns of FoFs, we assume that returns on cash are zero.[12]

Using the variables constructed in equations (1) and (2), we examine whether and how the trading decisions of FoFs are affected by investor flows. We sort the FoF-quarter observations into deciles of net flows. For each flow decile, Table II reports the averages

[12] The correlation between FoF assets and returns we infer from the regulatory filings and the corresponding values reported in the commercial databases are 0.97 and 0.90, respectively.

of the FoF flows, and the fractions of the underlying hedge fund holdings that are reduced, eliminated, expanded, added, or maintained. We observe greater fractions of hedge funds that are either eliminated or reduced and smaller fractions of funds that are expanded for the FoFs with lower flows. For example, FoFs experiencing the lowest flows (decile 1) eliminate 24%, reduce 28%, and expand 6% of their positions. In contrast, the eliminations, reductions, and expansions are 8%, 8%, and 37% respectively among the FoFs with the highest flows (decile 10).

To examine the average changes in FoFs' holdings, we also compute the change in the number of shares of each underlying hedge fund in a FoF portfolio as follows:

$$Change\ in\ holding_{j,i,t} = \frac{Value_{j,i,t}}{Value_{j,i,t} - Change\ in\ cost_{j,i,t-1\ to\ t}} - 1 \qquad (3)$$

where $Change\ in\ holding_{j,i,t}$ is the change in the number of shares of the underlying hedge fund *i* held by FoF *j* in quarter *t*. $Value_{j,i,t}$ is the market value of fund *i* held by FoF *j* at the end of quarter *t*. $Change\ in\ cost_{j,i,t-1\ to\ t}$ is the change in cost of fund *i* from the end of quarter *t-1* to *t*. We then compute the average of the change in holding of all the hedge funds *i* held by FoF *j* in quarter *t* as follows:

$$Average\ change\ in\ holding_{j,t} = \sum_{i=1}^{I} \frac{change\ in\ holding_{j,i,t}}{I} \qquad (4)$$

where *I* is the number of hedge fund holdings in a portfolio held by FoF *j* in quarter *t*.

The last column of Table II reports the *Average change in holding* of a FoF portfolio for each flow decile.[13] The average change in holding of underlying hedge funds is –29.56% and 15.67% for the FoFs with the lowest and highest flows, respectively. In

[13] Our computation of average change in holding for FoFs in Eq. (4) excludes additions because Eq. (3) is not defined for hedge fund positions that were not already held by the FoFs at the prior quarter end. Not surprisingly, therefore, the majority of the values in the final column are negative.

addition, the percentages of maintained positions are the least in the extreme flow deciles, which suggests that FoFs experiencing extreme outflows or inflows are more likely to change their positions. Overall, these results demonstrate that the trading decisions of FoFs are significantly influenced by investor flows.

3.2. Which hedge funds are sold by FoFs experiencing outflows?

In the previous section, we find that FoFs respond to outflows by selling underlying hedge funds. Next we investigate the extent to which the past performance and liquidity of the underlying funds influences the selling decisions of FoFs. It is conceivable that FoFs experiencing extreme outflows first sell their most liquid hedge funds even if those funds have performed relatively well and represent good investments otherwise. Note that we conduct our analysis using past performance and liquidity measured *relative* to other funds in the FoFs' portfolios, since the selling decisions of FoFs are confined to the funds in their own portfolios.

3.2.1. Univariate sorts on past performance and liquidity of funds in FoF portfolios

In Panels A and B of Table III, we include the underlying hedge fund positions that are reduced, eliminated, or maintained among the FoFs that experience negative investor flows (outflows) during the quarter. In Panel A, we sort the hedge fund positions by their relative performance (i.e., returns relative to other funds in the FoF portfolio) during the previous quarter, and report the average change in holding for the funds in each quartile. We observe that FoFs are more likely to sell hedge funds that have performed poorly in the recent past. For example, the average changes in holdings of the hedge funds in quartile 1 (the worst performers) and quartile 4 (the best performers) are

–17.46% and –14.21%, respectively. The worst performers in a FoF portfolio are, on average, sold 3.25% more (p-value<0.001) than the best performers. These findings resonate well with underperformance of managers driving the firing decisions of pension plan sponsors (Goyal and Wahal, 2008) and FoFs (Aiken, Clifford, and Ellis, 2014b).

In Panel B, the changes in holdings of the hedge funds with the lowest (quartile 1) and the highest (quartile 4) relative redemption restrictions are –21.37% and –17.19%, respectively. These figures imply that FoFs on average sell 4.18% more (p-value<0.001) hedge funds with the lowest redemption restrictions compared to their counterparts with the highest restrictions, although the relation between selling and restriction is not strictly monotonic.[14]

Although the typical FoF portfolio contains hedge funds that cover a wide range of redemption restrictions (see Table I, Panel B), some FoF portfolios contain a high concentration of either liquid or illiquid funds. In these situations, a relatively liquid fund may actually have a high redemption restriction in absolute terms when compared to other funds held across all FoFs. To address this concern, we repeat the analysis after sorting funds based on the absolute level of redemption restriction and again find greater selling among liquid funds. Specifically, from the lowest to highest quartiles of absolute redemption restriction, the average change in holding is –22.08%, –19.98%, –18.87%, and –16.86%, respectively, and the 5.22% spread between the highest and lowest quartiles is significant at the 0.01% level (not tabulated).

[14] Our findings that FoFs prefer to sell their more liquid hedge funds is similar to the empirical findings of Ben-David, Franzoni, and Moussawi (2012) and Boyson, Helwege, and Jindra (2013), who show that hedge funds experiencing redemptions prefer to sell liquid stocks. See also Scholes (2000) and Brown, Carlin, and Lobo (2010) for a theoretical discussion of optimal liquidation policy.

3.2.2 Bivariate sort on past performance and liquidity of funds in FoF portfolios

Table IV reports the average change in holding for each hedge fund group sorted by their relative past performance and relative redemption restriction ranks within a FoF portfolio. Panel A includes the eliminated, reduced, or maintained positions among the FoFs that experience negative investor flows. Among the hedge funds with the lowest relative redemption restriction (quartile 1), we observe that funds with worse past performance are sold more. For example, the average change in holding is –20.00% and –13.22% for the worst and best performers, respectively. The difference of 6.78% is both economically and statistically significant. This suggests that FoFs tend to sell poor past performers when the underlying hedge funds are very liquid. In contrast, among the most illiquid funds, we see virtually no relation between being sold and past performance (figures of –13.96% and –14.62% for the worst and best past performers, respectively in quartile 4 of redemption restriction are not significantly different from each other). Taken together, we conclude that FoF managers' preference of selling poor past performers is constrained by the redemption restriction imposed by the underlying funds.

We reach a similar conclusion when we compare the amount of selling of funds across liquidity quartiles while holding past performance fixed (i.e., moving along each column). Among the worst past performers (quartile 1), FoFs sell 6.04% less funds that have the highest compared to those that have lowest redemption restriction. The poor performers seem to be able to spare themselves, to some extent, from being sold by FoFs by having greater redemption restrictions in place.

Distressed FoFs have to raise cash to meet redemption requests. If there are not enough poorly performing liquid funds to sell, FoFs may need to sell liquid funds that have been performing well. Indeed, the average change in the holding of the best performers with the lowest redemption restriction (–13.22%) is about the same as that of the worst performers with the highest redemption restriction (–13.96%). The extent of being sold by distressed FoFs is about the same for the best and the worst performers because of the high redemption restriction imposed by the worst performers.

When FoFs experience extreme outflows, FoFs face even greater pressure to liquidate their investments in liquid hedge funds, even if these funds are performing relatively well. Panel B shows the selling activities of the FoFs that experience flows in the bottom fifth percentile (extreme outflows). We observe that the difference in change in holding between the best and the worst performers is no longer statistically significant, among the funds with the lowest redemption restriction. Strikingly, the best performers with the lowest redemption restriction are sold more than the worst performers that impose the highest redemption restriction. The change in holding of the best performers with the lowest redemption restriction is –70.37%, 37.19% significantly greater than that of the worst performers with the highest redemption restriction (–33.18%). These findings demonstrate the even *best-performing* liquid funds are sold by distressed FoF that experience extreme outflows.[15]

3.2.3. Multivariate analysis of FoF selling decisions

[15] Using an alternative, less-extreme (10^{th} percentile) cutoff for FoF outflows, we find qualitatively similar results. The selling by FoFs of their liquid best performers significantly exceeds that of their illiquid worst performers by 14.39%.

In this section, we estimate multivariate regressions to investigate which hedge funds are sold by FoFs experiencing outflows. For an easier interpretation of the coefficients, we estimate the regressions separately on the subsamples of funds with low (below median) and high (above median) relative redemption restriction in a FoF portfolio. In models (1) to (4) of Table V, the dependent variable is *change in holding*, i.e., the percent change in the number of shares of an underlying fund in a FoF portfolio.

As shown in model (1), the coefficient on past performance is positive (0.0773; *p*-value<0.001) for funds with low redemption restrictions. This indicates that, among the liquid funds, FoFs experiencing outflows tend to sell funds that have performed poorly. The coefficient of 0.0773 implies that the worst performer in the portfolio is sold more than the best performer by 7.73% of the shares held in the prior quarter. In contrast, the coefficient on past performance is not statistically significant in model (2) when we focus on the funds with high redemption restrictions. The difference of –0.059 in the coefficients on past performance between the low and high redemption restriction funds is highly significant. This suggests that FoFs' preference of selling poor past performers are constrained by the illiquidity of the underlying funds.

The coefficient of 0.793 (0.475) on FoF flows for the funds with low (high) redemption restrictions means that, if outflows increase by 50% of the FoF assets, the underlying funds are on average sold more by 39.65% (23.75%) of the shares held. The coefficient is significantly lower for the funds with high redemption restrictions, which suggests that flow-driven selling is attenuated by the illiquidity of the funds in FoF

portfolios. We find similar results in models (3) and (4) when the FoF and quarter fixed effects are included. These findings corroborate the univariate results in Table IV. [16]

Overall, the results demonstrate that outflow pressure forces FoFs to sell their underlying funds, especially their most liquid funds. FoFs also exhibit a preference to sell poorly performing funds. However, due to the redemption restrictions imposed by the underlying funds, well-performing funds that do not have high redemption restrictions also get sold. Next we examine the implications of this behavior by studying the future performance of hedge funds that are sold by FoFs experiencing outflows.

4. Impact of asset-liability liquidity mismatches on the constituent hedge funds

We may observe poor performance of the sold hedge funds either due to liquidity or information motives of FoFs. The liquidity motive suggests that redemptions from FoFs force hedge funds into distressed sales of their underlying assets, which can negatively impact security prices and reduce fund profitability. [17] The information motive suggests that FoF managers are informed and are able to identify hedge funds that are going to perform poorly in the future regardless of being sold by FoFs or not. Since we condition our empirical tests on a quasi-exogenous shock to demand for hedge funds from FoFs that need liquidity, there is a priori less reason to believe that sales of liquid funds are information motivated. Nevertheless, we further distinguish between these two

[16] We find qualitatively similar results when we estimate pooled regressions with interaction variables using the full sample rather than splitting the sample by redemption restriction.
[17] Prior literature has provided evidence of the phenomenon of fire sale of stocks by open-end mutual funds (Coval and Stafford, 2007) and closed-end mutual funds (Tang, 2013).

motives by conducting a battery of tests on sold funds after dividing them into sub-samples based on their exposure to the distressed sales of FoFs.

The premise of our first empirical test is as follows. If the poor post-sale performance is due to FoFs causing hedge funds to engage in distressed sales, we expect to observe poor performance in the funds with low redemption restrictions. Funds with low redemption restrictions have to sell assets in a shorter period of time in order to meet investor redemptions. In contrast, high redemption restrictions allow funds to liquidate securities in an orderly fashion and avoid distressed sales. The negative effect of distressed selling by FoFs on fund performance should be weakened, if not eliminated, by redemption restrictions. In contrast, if FoFs are not causing poor performance and can simply identify funds that will perform poorly in the future, we should observe poor performance in both subsamples. We estimate cumulative abnormal returns following the sale event to study the impact of FoFs' distressed sales on underlying hedge funds.

We follow Coval and Stafford (2007) and classify a fund to be involved in a distressed sale during a quarter if its *net pressure* is less than zero. *Net pressure* is equal to *pressure buys* minus *pressure sales*. *Pressure buys* are the aggregate buys of the fund's shares during the quarter by the FoFs that experience net flows in the top decile. *Pressure sales* are the aggregate sales of the fund's shares during the quarter by the FoFs that experience net flows in the bottom decile. We conduct our analysis for the subsamples of liquid and illiquid funds using a 31-day cutoff for redemption restrictions.

Next we compute cumulative abnormal returns (CARs) of hedge funds sold in distress using a peer-based benchmark. Specifically, we benchmark fund returns using the equally-weighted average returns of hedge funds that are held by registered FoFs in

the quarter and are in the same hedge fund styles as the sold funds. By matching on investment style, our abnormal returns are unlikely to be affected by differences in liquidity premium earned across funds.[18]

We compute CARs ranging from one quarter up to eight quarters after the funds are sold. As shown in Table VI, the sold funds with low redemption restrictions (less than or equal to 31 days) have negative CARs for all quarters after the distressed sales, ranging from –0.47% to –4.23%. For example, the average CAR is –3.28% (*p*-value<0.05) at the end of the 4th quarter and is –4.14% (*p*-value<0.01) at the end of the 8th quarter. These estimates are significant at conventional levels with the exception of quarter 1 (*t*-stat = –0.71). The CARs for the funds with high redemption restrictions (greater than 31 days) are not statistically significantly different from zero for any horizon ranging from 1 to 8 quarters. These results are consistent with the distressed sale hypothesis. Hedge funds with high redemption restrictions can sell assets in an orderly manner to meet the redemptions from FoFs. A high redemption restriction allows funds to avoid the cost of selling their assets at depressed prices, which funds with low redemption restrictions have to incur. These results do not support the information hypothesis. If FoFs had sold hedge funds for informational reasons, we should have also observed underperformance in the funds with high redemption restrictions.[19]

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[18] As further robustness, we repeat our analysis with benchmark returns calculated as the average returns of all funds within the same redemption frequency group (i.e., high or low). Our main results are qualitatively similar.

[19] For robustness, we also calculate alphas of calendar time portfolios that are formed at each quarter end by equally-weighting hedge funds that are sold in distress by FoFs in any of the previous four or eight quarters. Alphas are estimated as the intercept from a regression of the raw portfolio returns on the seven factors of Fung and Hsieh (2004) and the liquidity factor of Pástor and Stambaugh (2003). Using this alternative approach, we find qualitatively similar results.

Note that the post-sale fund underperformance is a long-run permanent effect (at least through eight quarters). This seems to run counter to the *temporary* "fire-sale" effects documented in prior studies of security-level returns (e.g., Coval and Stafford, 2007). However, as noted by Ozik and Sadka (2014), the effects on fund performance will be permanent if a distressed sale changes the composition of the fund's portfolio. For example, in the extreme case where a fund is forced to liquidate its entire portfolio or entire position in an underlying security, the liquidated fund will not experience the same return reversals as those of the underlying securities that were sold in the fire sale.

Next we conduct two more tests to further pin down the distressed sale hypothesis. In our second test, we repeat the CAR analysis on subsamples of FoFs. We expect stronger effects for funds with the biggest exposure to redemptions by distressed FoFs. For example, FoFs with a relatively high illiquidity gap have few sources of liquidity from which to raise cash and, in the event of outflows, would exert greater selling pressure on the few liquid funds that they do hold. The evidence in Panel B of Table VI shows that the subsequent underperformance of liquid funds is indeed greater among funds that are sold by FoFs with a high illiquidity gap (above the 75th percentile of illiquidity gap), as compared to those held by FoFs with a low illiquidity gap. For example, the average CAR ranges from –7.16% to –7.56% (p-value<0.05) between the 5th and 8th quarter, for the high illiquidity gap subsample, as compared to –2.38% to –2.74% for funds sold by low illiquidity gap FoFs. This difference is in the expected direction, but not statistically significant at conventional levels (t-stat = 1.41). However, when we repeat the analysis using the alternative measure of illiquidity gap we find significant results for the difference (see Panel A of Table X). We interpret this as further

evidence that the flow-motivated redemptions of FoFs cause sold funds to underperform benchmarks.

Our third and final test is based on the idea that, in anticipation of redemptions by FoFs, liquid hedge funds may take steps to reduce the impact of redemptions on fund performance, for example, by holding more liquid securities.[20] Therefore, we expect stronger effects when FoF redemptions represent an unexpected liquidity shock to the hedge funds targets. To test this hypothesis, we focus on the subsample of hedge funds that have recently performed well. Better-performing funds can plausibly expect greater investor flows (and fewer redemptions), given the existing evidence of a positive flow-performance relation (e.g., Agarwal, Daniel, and Naik, 2006; Brown et al., 2008; Getmansky et al., 2010). In Panel C we repeat our tests after subdividing the liquid hedge funds based on their style-adjusted returns in the prior quarter. The results strongly show that the underperformance of liquid funds sold by FoFs is indeed more evident among the subsample of funds with relatively better recent performance. While we also estimate a negative abnormal return among poorly performing funds that are sold by FoFs, none of the effects are significant. This evidence lends support to the hypothesis that the effects of FoF redemptions are greatest when they represent a shock to liquid funds.

5. Impact of asset-liability liquidity mismatches on FoFs

5.1. Do liquid star hedge funds avoid FoF investments?

[20] Teo (2010) finds that agency problems lead many managers of liquid hedge funds to be exposed to excessive liquidity risk, suggesting that hedge fund managers may not manage liquidity risk in ways that reduce the impact of fund flows on performance.

Our results so far show that FoFs experiencing outflows tend to sell their liquid hedge funds, including even well-performing funds. These sold funds subsequently perform poorly, especially those sold by FoFs with larger asset-liability liquidity mismatches (i.e., illiquidity gaps). Given this potential cost of having FoFs as investors, do the best-performing ("star") liquid funds avoid investments from FoFs, especially those with larger illiquidity gaps and therefore more prone to engage in distressed sales? Presumably, star funds should not have much difficulty raising capital from other sources. In addition, since illiquid star hedge funds do not have to bear the negative externalities associated with distressed selling by FoFs, we would not expect them to avoid investment from FoFs with high illiquidity gaps. [21]

To test this hypothesis, we study whether liquid star funds represent a lower proportion of a FoF's total investment in liquid hedge funds when the FoF has a large illiquidity gap. Specifically, we use this proportion for a given FoF during a quarter as the dependent variable in a regression with the illiquidity gap of the same FoF in the prior quarter being the key independent variable. We likewise estimate the regression using the FoF's proportional investment in star illiquid hedge funds. We define star funds as the top 10% performers, where performance is measured using raw or style-adjusted fund returns in the prior two years. Liquid funds are the funds with a redemption frequency of less than or equal to 31 days while illiquid funds are funds with redemption restriction of greater than 365 days.

[21] Several studies present return-based evidence that FoFs underperform benchmarks, including Brown, Goetzmann, and Liang (2004), Ang, Rhodes-Kropf, and Zhao (2008), Agarwal and Kale (2007). Sialm, Sun, and Zheng (2013) find that FoFs exhibit a local bias that leads to contagion among geographically-proximate funds.

We report the results in Table VII. Models (1) to (4) correspond to results for liquid star funds using both raw returns and style-adjusted returns as performance measures, and with and without additional control variables. Control variables include the net flows and returns of the FoFs in the previous quarter. Quarter fixed effects are included and standard errors are clustered at the quarter level. Models (5) to (8) report the results for the same specifications for the illiquid star hedge funds.

As shown in models (1) to (4), the coefficients on lagged illiquidity gap are negative and statistically significant across all models, which suggests that liquid star funds are a smaller proportion of FoF's total investment in liquid funds when these FoFs have larger illiquidity gaps. Specifically, we find that an increase in illiquidity gap of 100 days is associated with a 0.3% lower FoF investment in star liquid funds as a proportion of all liquid funds held by the FoF. While this magnitude may seem small when compared to the average FoF investment across all funds (see Table 1, Panel A), it is large relative to the average FoF investment in star liquid funds (1.1%). Furthermore, we find that star illiquid hedge funds (Models (5) to (8)) do not exhibit a reluctance to accept capital from FoFs with high illiquidity gaps. Panel B of Table X shows similar findings when we repeat the analysis using the alternative measure of illiquidity gap.

Taken together, these results are consistent with our hypothesis that liquid star funds, and not illiquid star funds, are likely to avoid investments from FoFs with higher illiquidity gaps. As documented earlier, FoFs experiencing outflows may be forced to sell the liquid funds in their portfolios, even if these funds have been performing well, while the illiquid funds are insulated from the funding liquidity shocks experienced by the FoFs. Such a liquidity spillover from illiquid to liquid funds in a FoF portfolio is

more likely to occur in FoFs with larger illiquidity gaps, and therefore such FoFs may be particularly avoided by liquid star hedge funds.

5.2. How does illiquidity gap affect FoF performance?

The greater the illiquidity mismatch between the assets and liabilities of FoFs, the higher the likelihood that FoFs have to engage in distressed sales of their funds when FoFs experience outflows, which are likely to be significant during a crisis period. This motivates our investigation of how a FoF's asset-liability liquidity mismatch is related to its performance across different market conditions.

The underlying premise for our analysis is as follows. When the illiquidity of assets is greater than that of liabilities, FoFs are essentially bearing funding liquidity risk. During normal times, such FoFs should earn a liquidity premium. However, during periods of crisis, FoFs experiencing extreme outflows will have to engage in distressed sales of the underlying funds, more likely the liquid ones, to meet redemptions. In contrast, if illiquidity of assets is less than that of the liabilities, FoFs are restricting investor withdrawal but not making illiquid investments. Such a conservative strategy that maintains a liquidity cushion will prevent FoFs from earning a liquidity premium during normal times but benefit them during a crisis. Therefore, we expect that FoFs with larger illiquidity gaps should exhibit better performance during normal times but perform worse during a crisis.[22]

[22] Consistent with this intuition, Bai, Krishnamurthy, and Weymuller (2014) find that banks with a greater liquidity mismatch experience more negative stock returns during the crisis, but more positive returns in non-crisis periods.

We recognize that the illiquidity gap is a choice made by the FoFs, and therefore we model its determinants to account for the endogenous nature of the illiquidity gap. Specifically, to study the causal relation between illiquidity gap and FoF performance, we follow a two-stage least squares (2SLS) approach to address endogeneity. To execute this approach, we follow prior studies on mutual fund and hedge fund performance and use family size at fund inception as an instrumental variable (Teo, 2011; Ramadorai, 2012; Chen et al., 2013). The underlying argument for the validity of this instrument is that the family size at fund inception should not directly affect FoF performance at a date far away in the future from the inception date. On the contrary, we would expect family size to be positively correlated with illiquidity gap, as funds operated by larger families should have lower exposures to funding liquidity risk, and can therefore maintain larger illiquidity gaps. As noted by Teo (2011), the rationale for this conjecture is that larger families can attract capital from several investors and have greater access to credit provided by prime brokers.

Table VIII reports the results of the 2SLS procedure. Column (1) reports the result from the first stage where we regress a FoF's illiquidity gap on several fund characteristics, including the logarithm of fund company size at the date of fund's inception. We find a significant relation between illiquidity gap and several fund characteristics used as control variables. Importantly, as argued above, the instrumental variable (family size) is positive and highly significant. Column (2) reports the results from the second stage. Specifically, we regress a FoF's quarterly returns on the predicted value of lagged illiquidity gap from the first stage, an indicator variable for the crisis period (2007–2009), and its interaction with predicted illiquidity gap. We also control for

all FoF characteristics included in the first stage as well as their interaction with the crisis dummy (not reported in the table for brevity).

The positive and statistically significant coefficient on illiquidity gap (coeff. = 0.0220; *t*-stat = 1.70) is consistent with our hypothesis that FoFs bearing higher liquidity risk perform better during the non-crisis periods. A one standard deviation increase in the illiquidity gap of 72.4 days is associated with 1.6% greater quarterly returns. The interaction of crisis indicator variable and illiquidity gap is negative and statistically significant (coeff. = –0.0511; *t*-stat = –2.20). This suggests that FoFs with higher illiquidity gaps perform poorly during periods of crisis. During the crisis period, a one standard deviation increase of illiquidity gap is associated with 2.1% *lower* quarterly returns. Panel C of Table X reports similar results from the analysis using the alternative measure of illiquidity gap.[23]

5.3 Do illiquidity gaps in FoFs lead to investor runs?

The worse performance of FoFs with higher illiquidity gaps during crises can be related to the strategic complementarities among investors. The theoretical underpinnings of this phenomenon can be found in the context of mutual funds (Chen, Goldstein, and Jiang, 2010) and hedge funds (Liu and Mello, 2011). In our setting, this situation arises in the case of FoFs with high illiquidity gaps, because investors can anticipate both a lack of available liquidity and the adverse effects of distressed sales by FoFs. This can, in turn,

[23] For robustness, we have implemented a similar 2SLS procedure that treats the interaction variable involving the endogenous variable (Illiquidity gap x Crisis dummy) also as an endogenous variable following Wooldridge (2010). We find qualitatively similar results.

subject the FoFs to runs where some investors pre-emptively withdraw their capital before others.

To address this question we examine whether the sensitivity of FoF investor flows to past performance is related to illiquidity gaps, especially when FoFs perform poorly. For this purpose we regress quarterly FoF flows (Eq. (2)) on the positive and negative components of prior quarter's returns, illiquidity gap, and an interaction of the returns components and illiquidity gap. We control for several FoF characteristics and include FoF fixed effects to control for time-invariant unobservable FoF attributes. The standard errors are clustered at the quarter level. Our main variable of interest is the interaction between the negative return component and illiquidity gap. Theories of strategic complementarities would predict a positive coefficient on this interaction variable, which would indicate a greater sensitivity of flows to poor performance among FoFs with greater illiquidity gaps.

Our results reported in Table IX are consistent with this prediction. Specifically, we observe uniformly that the interaction term between the negative return component and illiquidity gap is positive and significant across all specifications. In addition to being statistically significant, these findings are economically meaningful. For example, in Model 2 we estimate that a drop in returns from 0% to -10% is associated with a 5.94% decrease in quarterly flows, among FoFs with no illiquidity gap. However, a one standard deviation increase in illiquidity gap would lead to a further 4.71% decline in investor flows. Panel D of Table X reports similar results from the analysis using the alternative measure of illiquidity gap.

In summary, we find that greater asset-liability liquidity mismatches in FoFs have important effects on FoFs, including a reduced access to the best-performing liquid funds and lower performance during crisis periods. Furthermore, a greater illiquidity gap can lead to runs that amplify the funding liquidity risk in FoFs.

6. Concluding Remarks

Fund of hedge funds (FoFs) can invest in very illiquid hedge funds while offering generous liquidity terms to their investors. While mismatches of this sort can allow FoFs to earn higher returns during normal periods, it can also expose them to funding liquidity risk during a crisis. This paper studies the impact of funding liquidity risk on the underlying hedge funds held by FoFs as well as the FoFs themselves. We propose a new variable, *illiquidity gap*, which measures the mismatches between the liquidity of a FoF's investments and the liquidity offered by the FoF to its investors. We show that FoFs respond to capital outflows by reducing their investments in hedge funds with the most liquid redemption terms, and these hedge funds subsequently experience worse performance, especially those held by FoFs with greater illiquidity gaps.[24]

Our findings also suggest that FoFs, especially those with high illiquidity gaps, are unattractive investors for liquid star hedge funds. The reason is that a FoF is sometimes forced to liquidate its best-performing funds with lower redemption

[24] Our paper uncovers a new source of liquidity risk among funds that are otherwise considered relatively liquid. While our findings provide the ex post effects of funding liquidity shocks of FoFs on the liquid funds, investors in liquid funds may require higher expected returns for bearing the liquidity spillover risk from the commingling of liquid funds with illiquid funds in FoF portfolios, especially those with high illiquidity gaps. Future research can examine such ex ante effects on the pricing of this liquidity spillover risk using secondary market transactions as in Ramadorai (2012, 2013).

restrictions due to liquidity shortfalls elsewhere in the FoF's portfolio. Furthermore, we find that a larger illiquidity gap is indicative of greater funding liquidity risk in FoFs, as it predicts worse FoF performance during a market crisis. Finally, we also find that illiquidity gaps can make FoFs vulnerable to runs and exacerbate funding liquidity risk, as evident by a greater response of FoF investor flows to past poor performance. Taken together, the evidence in this paper highlights the importance of asset-liability liquidity management for hedge funds and their investors.

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Table I: Summary statistics

This table reports the summary statistics of the characteristics and redemption restrictions of FoF portfolios. In Panel A, *assets under management (AUM)* are the net assets of a FoF at a quarter end, *Number of holdings* is the number of hedge fund positions in a FoF portfolio, and *Position size* is the market value of a hedge fund position in a FoF portfolio and is reported in both dollars and as a percentage of FoF assets. Panel B reports the range and standard deviation of the redemption restriction of the underlying hedge funds in a FoF portfolio. *Redemption restriction* is the inverse of an underlying hedge fund's redemption frequency and is in the unit of days, e.g., if a hedge fund allows their investors to redeem shares semiannually, its redemption restriction is equal to 365/2 days. In Panel C, *Redemption restriction of the assets* is the value-weighted average of the redemption restriction of the underlying hedge funds in a FoF portfolio, *Redemption restriction of the liabilities* is the redemption restriction that a FoF imposes on its investors, and *Illiquidity gap* is the difference in the redemption restriction between the assets and the liabilities of a FoF portfolio. *, **, *** and **** denote statistical significance at 10, 5, 1 and 0.1 percent level, respectively.

Variable	Obs	Mean	P25	P50	P75	SD
Panel A. The characteristics of FoF portfolios						
AUM (million $)	1303	328	53.9	125	281	684
Number of Holdings	1303	26.73	15.00	23.00	31.00	20.08
Position Size (million $)	1303	11.00	2.25	5.25	12.30	16.00
Position Size (% of AUM)	1300	5.68	2.97	3.97	5.79	16.55
Panel B. The variation in the redemption restriction of the underlying hedge funds in FoF portfolios						
Range	1286	330.91	274.00	335.00	335.00	198.61
Standard Deviation	1276	104.49	76.04	104.94	127.54	51.73
Panel C. The redemption restriction of the assets and the liabilities of FoF portfolios						
Redemption restriction of FoF liabilities	1119	141.45	91.00	91.00	180.00	62.48
Redemption restriction of FoF assets	1119	117.39	80.95	111.81	151.27	50.63
Illiquidity gap (assets – liabilities)	1119	–24.07****	–58.89	–17.81	17.13	72.41

Table II: The flows and the trading decisions of FoFs

This table reports the trading decisions of FoFs in relation to investor flows. For each flow decile, the table reports the averages of the FoF flows; the fraction of the underlying hedge funds that are eliminated, added, expanded, reduced, and maintained; and the average change in holding in a FoF portfolio. *Flow* is the change in FoF assets in a quarter after removing the change in assets due to FoF returns and dividing by the FoF assets at the previous quarter end. *Average change in holding* is the average percentage change in the number of shares of the underlying hedge funds held by a FoF in a quarter.

		Fraction of positions					Average change in holding (%)
Decile	Flow (%)	Added	Eliminated	Expanded	Reduced	Maintained	
1 (Lowest)	–27.90	0.12	0.24	0.06	0.28	0.42	–29.56
2	–9.00	0.08	0.10	0.06	0.25	0.59	–13.18
3	–4.60	0.09	0.09	0.06	0.16	0.68	–11.21
4	–1.56	0.13	0.10	0.09	0.17	0.64	–11.69
5	0.13	0.05	0.07	0.09	0.11	0.73	–6.33
6	1.69	0.08	0.08	0.11	0.12	0.68	–7.07
7	3.50	0.10	0.07	0.13	0.10	0.70	–1.93
8	6.48	0.15	0.08	0.17	0.12	0.62	–3.55
9	11.53	0.13	0.10	0.24	0.09	0.58	–0.78
10 (Highest)	48.20	0.15	0.08	0.37	0.08	0.48	15.67

Table III: Redemption restriction, past performance, and the trading decisions of FoFs (univariate sort)

The table reports the average change in holding of the underlying hedge funds in FoF portfolios in relation to hedge funds' past performance (measured during the prior quarter) and redemption restriction. Panels A and B include the underlying hedge fund positions that are reduced, eliminated, or maintained among the FoFs that experience negative investor flows (outflows) during the quarter. The sample period is from 2004 to 2011. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

Panel A. *The relative past performance of the underlying hedge funds and the selling decisions of FoFs*

Quartile	Relative past performance rank	Change in holding (%)	
1 (Worst)	14.19	–17.46	
2	38.65	–15.45	
3	63.51	–13.51	
4 (Best)	89.14	–14.21	
Difference (4–1)		3.25	****

Panel B. *The relative redemption restriction of the underlying hedge funds and the selling decisions of FoFs*

Quartile	Relative redemption restriction	Change in holding (%)	
1 (Lowest)	19.07	–21.37	
2	44.77	–18.18	
3	59.01	–21.06	
4 (Highest)	87.11	–17.19	
Difference (4–1)		4.18	****

Table IV: Redemption restriction, past performance, and the selling decisions of FoFs (double sort)

This table reports the average change in holding for each hedge fund group sorted by hedge funds' relative past performance (measured during the prior quarter) and relative redemption restriction ranks within a FoF portfolio. Panels A and B include the sold and maintained positions among the FoFs that experience negative flows (outflows) and bottom fifth percentile flows (extreme outflows), respectively. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

Panel A. Negative flows (outflows)

		Relative Past Performance				
		1 (Worst)	2	3	4 (Best)	Difference (4–1)
Relative redemption restriction	1 (Lowest)	–20.00	–17.04	–16.32	–13.22	6.78****
	2	–18.11	–12.58	–13.35	–13.31	4.8***
	3	–18.53	–17.35	–13.81	–16.59	1.94
	4 (Highest)	–13.96	–13.03	–12.45	–14.62	–0.66
	Difference (4–1)	6.04****	4.01*	3.87***	–1.4	
	Difference (14–41)	–0.74				

Panel B. Bottom fifth percentile flows (extreme outflows)

		Relative Past Performance				
		1 (Worst)	2	3	4 (Best)	Difference (4–1)
Relative redemption restriction	1 (Lowest)	–73.64	–67.49	–70.11	–70.37	3.27
	2	–38.77	–46.93	–49.16	–19.55	19.22
	3	–55.35	–45.06	–47.69	–69.10	–13.75
	4 (Highest)	–33.18	–33.57	–35.13	–43.58	–10.40
	Difference (4–1)	40.46***	33.92***	34.98***	26.79*	
	Difference (14–41)	37.19***				

Table V: Redemption restriction, past performance, and the selling decisions of FoFs (multivariate regressions)

This table reports the results of regressing the selling decisions of FoFs on FoF flows and relative past performance (measured during the prior quarter) of underlying hedge funds in FoF portfolios. The dependent variable is *change in holding*, i.e., the percentage change in the number of shares of an underlying hedge fund in a FoF portfolio. The expanded or added positions are excluded and only the quarters when FoFs experience outflows are included. The regressions are estimated separately on the sub-samples of hedge funds with low (below median) and high (above median) relative redemption restrictions. Standard errors are clustered at the quarter level. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

	Change in holding					
	(1)	(2)		(3)	(4)	
	Relative redemption restriction					
	Low	High	Difference	Low	High	Difference
Relative past	0.0773****	0.0183	–0.059****	0.0742****	0.0182	–0.056***
performance	(4.51)	(1.05)		(4.03)	(1.04)	
FoF flow	0.793****	0.475***	–0.218****	0.657****	0.435****	–0.222***
	(10.33)	(3.58)		(8.42)	(7.77)	
Constant	–0.127****	–0.115****		–0.183	0.136****	
	(–10.52)	(–7.52)		(–0.67)	(4.68)	
Observations	5101	5532		5101	5532	
R-squared	0.088	0.053		0.145	0.117	
Quarter FE	No	No		Yes	Yes	
FoF FE	No	No		Yes	Yes	

Table VI: Cumulative abnormal returns of hedge funds sold in distressed sales

This table reports the cumulative abnormal returns of underlying hedge funds over one to eight quarters after being sold in distressed sales by FoFs. We define a sale as a distressed sale when the *net pressure* is less than zero. *Net pressure* is equal to *pressure buys* minus *pressure sales*. *Pressure buys* are the aggregate buys of the fund's shares during the quarter by the FoFs that experience net flows in the top decile. *Pressure sales* are the aggregate sales of the fund's shares during the quarter by the FoFs that experience net flows in the bottom decile. The benchmark returns are the equally-weighted average returns of hedge funds that are held by registered FoFs in the quarter and are in the same hedge fund styles as the hedge funds sold in distressed sales. In Panel A, the cumulative abnormal returns are reported for the full sample and the sub-samples with low and high redemption restrictions. In Panel B, the sold hedge funds with low redemption restrictions are further divided into two subsamples based on the illiquidity gap of the FoFs. In Panel C, the sold hedge funds with low redemption restrictions are further divided into two subsamples based on their style-adjusted returns in the prior quarter. Standard errors are clustered at the quarter level. *, **, ***, and **** denote statistical significance at 10, 5, 1 and 0.1 percent level, respectively.

Panel A. High vs. low redemption restrictions

	Cumulative Abnormal Returns							
	1 quarter	2 quarters	3 quarters	4 quarters	5 quarters	6 quarters	7 quarters	8 quarters
Low redemption restriction (<=31 days)								
(#obs.= 187)	–0.0047	–0.0186*	–0.0223*	–0.0328**	–0.0394***	–0.0423***	–0.0390***	–0.0414***
	(–0.71)	(–1.67)	(–1.99)	(–2.61)	(–3.21)	(–2.99)	(–2.86)	(–3.35)
High redemption restriction (>31 days)								
(#obs.= 604)	0.0004	0.0017	0.0060	0.0035	–0.0002	0.0011	–0.0027	–0.0023
	(0.09)	(0.23)	(0.65)	(0.34)	(–0.02)	(0.08)	(–0.19)	(–0.16)
Difference (Low–High)								
	–0.0052	–0.0203	–0.0283*	–0.0363**	–0.0391**	–0.0434**	–0.0362*	–0.0390*
	(0.59)	(1.42)	(1.67)	(1.97)	(1.97)	(2.07)	(1.64)	(1.67)

Panel B. High vs. low illiquidity gap

	Cumulative Abnormal Returns							
	1 quarter	2 quarters	3 quarters	4 quarters	5 quarters	6 quarters	7 quarters	8 quarters
High Illiquidity Gap (Gap is above 75 percentile)								
(# obs. = 52)	–0.0055	–0.0352	–0.0341	–0.0453	–0.0730**	–0.0756**	–0.0733**	–0.0716**
	(–0.52)	(–1.37)	(–1.30)	(–1.69)	(-2.57)	(–2.13)	(–2.23)	(–2.25)
Low Illiquidity Gap (Gap is below 75 percentile)								
(# obs. = 139)	–0.0041	–0.0106	–0.0155	–0.0254*	–0.0246*	–0.0269*	–0.0238	–0.0274**
	(–0.59)	(–1.20)	(–1.39)	(–1.83)	(–1.82)	(–2.07)	(–1.71)	(–2.34)
Difference (High–Low)								
	–0.0014	–0.0246	–0.0186	–0.0199	–0.0484	–0.0487	–0.0495	–0.0442
	(0.11)	(1.03)	(0.65)	(0.62)	(1.41)	(1.40)	(1.45)	(1.19)

Panel C. Positive vs. negative past abnormal returns

	Cumulative Abnormal Returns							
	1 quarter	2 quarters	3 quarters	4 quarters	5 quarters	6 quarters	7 quarters	8 quarters
Past abnormal return>0								
(# obs. = 83)	–0.0166	–0.0546***	–0.0608***	–0.0651***	–0.0633***	–0.0639**	–0.0638***	–0.0723***
	(–1.39)	(–3.14)	(–3.17)	(–3.22)	(–2.95)	(–2.74)	(–2.98)	(–3.44)
Past abnormal return<0								
(# obs. = 97)	0.0037	0.0089	0.0081	–0.0066	–0.0197	–0.0249	–0.0196	–0.0178
	(0.34)	(0.55)	(0.49)	(–0.34)	(–1.33)	(–1.56)	(–1.20)	(–1.03)
Difference (High-Low)								
	–0.0203*	–0.0635**	–0.0689**	–0.0585**	–0.0436	–0.0390	–0.0442	–0.0545
	(–1.73)	(–2.89)	(–2.63)	(–1.96)	(–1.35)	(–1.19)	(–1.38)	(–1.57)

Table VII: Illiquidity gap and FoF investments in star funds

This table reports the results from regressing the dollar amount of liquid (illiquid) star hedge funds that a FoF invests in a quarter, scaled by the total dollar amount of liquid (illiquid) hedge funds the FoF invests in the quarter, on the illiquidity gap of the FoF in the previous quarter. Star funds are defined as the top 10% performers, where performance is measured using raw or style-adjusted returns in the previous two years. Liquid (illiquid) funds are the funds with a redemption frequency of less than or equal to 31 days (greater than 365 days). Control variables include the flows in or out of the FoF and the return of the FoF in the previous quarter. Quarter fixed effects are included. The *t*-statistics are reported in parentheses below the slope coefficients. Standard errors are clustered at the quarter level. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

	Liquid star funds				Illiquid star funds			
	Raw return		Style-adjusted return		Raw return		Style-adjusted return	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged illiquidity gap	−0.00295***	−0.00336***	−0.00218**	−0.00278***	0.000251	0.000279	0.000196	0.000213
	(−3.23)	(−3.42)	(−2.64)	(−3.31)	(0.84)	(0.86)	(0.66)	(0.66)
Lagged FoF flow		0.507		0.482		−0.00345		−0.00350
		(0.95)		(0.90)		(−0.13)		(−0.13)
Lagged FoF return		10.84**		12.50***		−0.0832		0.0158
		(2.43)		(2.85)		(−0.09)		(0.02)
Constant	1.190****	1.421****	1.215****	1.693****	0.151****	0.00271	0.149****	0.00409
	(38.73)	(13.02)	(43.65)	(15.19)	(14.97)	(0.13)	(14.93)	(0.20)
Observations	1051	988	1051	988	1051	988	1051	988
R-squared	0.072	0.080	0.041	0.051	0.065	0.065	0.071	0.071
Quarterly fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table VIII: Illiquidity gap and FoF performance

This table reports the results of the two-stage least squares (2SLS) regressions. First stage (1) regresses a FoF illiquidity gap on several fund characteristics, including the logarithm of fund company size at fund inception (*logcompany size at inception date*) as an instrumental variable. Fund characteristics include lagged investor flows (*lagged FoF_flow*), assets under management (*lagged logFoFsize*), age (*lagged logFoFage*), management fee (*lagged managementfee*), incentive fee (*lagged incentivefee*), and an indicator variable for high watermark (*lagged highwatermark*). Second stage (2) regresses FoF quarterly returns on the first-stage predicted illiquidity gap, an indicator variable for crisis (*crisis dummy*), and the interaction of the two. Second stage regressions include all first-stage variables, a crisis dummy, and its interactions with fund characteristics (not reported for brevity). Standard errors are clustered at the quarter level. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

	First stage (1)	Second stage (2)
	lagged Illiquidity gap (1)	FoF returns (2)
Fitted values of lagged illiquidity gap from the first stage		0.0220*
		(1.70)
Fitted value of lagged illiquidity gap x crisisdummy		–0.0511**
		(–2.20)
lagged FoF_flow	0.0999***	–0.000398
	(3.61)	(–0.14)
lagged logFoFsize	–0.0714****	–0.000816
	(–3.95)	(–0.40)
lagged logFoFage	–0.719****	0.00462
	(–11.24)	(0.48)
lagged managementfee	–0.803****	0.0215
	(–4.76)	(1.42)
lagged incentivefee	0.0447****	0.000322
	(5.87)	(0.44)
lagged highwatermark	–0.928****	0.00761
	(–14.21)	(0.56)
logcompany size at inception date	0.0314****	
	(7.38)	
crisisdummy & its interactions with fund characteristics	Yes	Yes
Constant	4.406****	–0.00925
	(8.34)	(–0.14)
Observations	496	470
R–squared	0.420	0.087

Table IX: Illiquidity gap and flow-performance sensitivity

This table reports the results of regressing quarterly FoF flows on the positive (*positive lagged FoF_ret*) and negative (*negative lagged FoF_ret*) components of the lagged quarterly FoF returns, lagged illiquidity gap, and their interaction. Variables *positive lagged FoF_ret* and *negative lagged FoF_ret* are computed as the max(FoF returns, 0) and min(FoF returns, 0), respectively. Models 2 and 4 control for several FoF characteristics that have been defined earlier in Table VIII, and Models 3 and 4 include FoF fixed effects. Standard errors are clustered at the quarter level. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

	FoF Flows			
	(1)	(2)	(3)	(4)
positive lagged FoF_ret	0.169	0.741	0.123	0.905
	(0.26)	(0.71)	(0.19)	(0.77)
positive lagged FoF_ret x lagged illiquidity gap	–0.0780	0.200	0.182	0.621
	(–0.11)	(0.20)	(0.26)	(0.57)
negative lagged FoF_ret	0.929****	0.594*	1.151***	0.633*
	(3.91)	(1.97)	(3.59)	(1.91)
negative lagged FoF_ret x lagged illiquidity gap	0.728****	0.651***	0.921***	0.584**
	(4.01)	(3.24)	(2.91)	(2.56)
lagged illiquidity gap	0.0476***	0.0231	0.0582**	0.0584
	(2.95)	(1.32)	(2.22)	(1.53)
lagged FoF_flow	0.0115	–0.0493	–0.0567	–0.115
	(0.15)	(–0.37)	(–0.53)	(–0.78)
lagged logFoFsize		–0.0186		–0.345
		(–0.49)		(–1.45)
lagged logFoFage		–0.130***		–0.0210
		(–2.78)		(–0.18)
lagged managementfee		–0.0861		–0.198
		(–1.16)		(–1.15)
lagged incentivefee		–0.00523		–0.0310
		(–1.46)		(–1.37)
lagged highwatermark		–0.0425		0.280
		(–0.78)		(0.67)
Constant	0.0293*	1.044	–0.351	6.417*
	(1.74)	(1.12)	(–1.51)	(1.71)
FoF fixed effects	No	No	Yes	Yes
Observations	988	500	988	500
R-squared	0.015	0.050	0.112	0.226

Table X: Robustness check with an alternative measure of illiquidity gap

This table reports the results from Tables VI Panel B, VII, VIII, and Table IX using an alternative measure of illiquidity gap defined as the percentage of a FoF's assets with a longer redemption frequency than that which is applied to the FoF's own investors. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

Panel A. Table VI Panel B: Cumulative abnormal returns of hedge funds sold in distressed sales

	Cumulative Abnormal Returns							
	1 quarter	2 quarters	3 quarters	4 quarters	5 quarters	6 quarters	7 quarters	8 quarters
High Illiquidity Gap (Alternative Gap is above 50 percentile)								
	0.00576	−0.0294	−0.0445	−0.0635*	−0.0934**	−0.0955**	−0.0834**	−0.0909***
(# obs = 66)	(0.57)	(−1.35)	(−1.72)	(−2.06)	(−2.76)	(−2.72)	(−2.66)	(−3.04)
Low Illiquidity Gap (Alternative Gap is below 50 percentile)								
	−0.00971	−0.0143	−0.0157	−0.0197	−0.0106	−0.0129	−0.0138	−0.0114
(# obs = 129)	(−1.12)	(−1.13)	(−1.21)	(−1.68)	(−0.89)	(−0.95)	(−0.95)	(−0.83)
Difference (High-Low)	0.0155	−0.0151	−0.0288	−0.0438	−0.0828**	−0.0826**	−0.0695**	−0.0795**
	(1.32)	(−0.67)	(−1.04)	(−1.41)	(−2.58)	(−2.57)	(−2.17)	(−2.28)

Panel B. Table VII: Illiquidity gap and FoF investments in star funds

	Liquid star funds				Illiquid star funds			
	Raw return		Style adjusted return		Raw return		Style adjusted return	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Lagged illiquidity gap	−0.0207****	−0.0219****	−0.0227****	−0.0248****	0.000410	0.000440	−0.0000857	0.000203
	(−5.08)	(−4.74)	(−6.19)	(−6.45)	(0.32)	(0.34)	(−0.06)	(0.15)
Lagged FoF flow		0.00399		0.00375		0.000247		0.000206
		(0.84)		(0.79)		(0.67)		(0.58)
Lagged FoF return		0.0950*		0.127****		−0.00641		−0.00545
		(2.01)		(3.79)		(−0.71)		(−0.60)
Constant	0.00963****	0.0134****	0.0108****	0.0139****	0.00344****	0.00218****	0.00284****	0.00113****
	(19.67)	(13.47)	(24.48)	(16.34)	(22.74)	(13.57)	(17.71)	(7.06)
Observations	1219	1144	1219	1144	1219	1144	1219	1144
R-squared	0.073	0.081	0.051	0.062	0.053	0.053	0.049	0.052
Quarterly fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel C. Table VIII: Illiquidity gap and FoF performance

	First stage	Second stage
	lagged Illiquidity gap	FoF returns
Fitted values of lagged illiquidity gap from the first stage regression		0.0927*
		(1.70)
Fitted value of lagged illiquidity gap x crisisdummy		–0.216**
		(–2.20)
lagged FoF_flow	–0.00607	0.00236
	(–0.68)	(1.22)
lagged logFoFsize	–0.0224****	–0.000307
	(–4.46)	(–0.14)
lagged logFoFage	–0.0777***	–0.00400
	(–3.69)	(–0.51)
lagged managementfee	–0.0887**	0.0121
	(–2.07)	(1.06)
lagged incentivefee	0.0126****	0.000137
	(6.92)	(0.17)
lagged highwatermark	–0.116****	–0.00208
	(–5.83)	(–0.25)
logcompany size at inception date	0.00744****	
	(6.45)	
Constant	0.854****	0.00846
	(6.98)	(0.15)
Observations	496	470
R–squared	0.211	0.087

Panel D. Table IX: Illiquidity gap and flow-performance sensitivity

	FoF Flows			
	(1)	(2)	(3)	(4)
positive lagged FoF_ret	0.678	1.600	0.476	1.254
	(0.85)	(1.22)	(0.61)	(0.99)
positive FoF_ret x illiquidity gap	–2.385	–4.158	–1.610	–1.676
	(–1.15)	(–1.32)	(–0.86)	(–0.73)
negative lagged FoF_ret	0.158	–0.125	0.262	–0.0772
	(0.63)	(–0.30)	(1.00)	(–0.13)
negative FoF_ret x illiquidity gap	2.943**	2.104	3.043**	1.970
	(2.68)	(1.05)	(2.17)	(1.01)
Illiquidity gap	0.133**	0.227**	0.167*	0.225
	(2.35)	(2.21)	(2.01)	(1.63)
lagged FoF_flow	0.0176	–0.0469	–0.0528	–0.105
	(0.26)	(–0.40)	(–0.52)	(–0.78)
lagged logFoFsize		–0.0200		–0.343
		(–0.50)		(–1.44)
lagged logFoFage		–0.137**		–0.0295
		(–2.65)		(–0.25)
lagged managementfee		–0.0994		–0.211
		(–1.09)		(–1.19)
lagged incentivefee		–0.00545**		–0.0316
		(–2.18)		(–1.48)
lagged highwatermark		–0.0518		0.335
		(–0.71)		(0.79)
Constant	–0.00827	1.064	–0.389	6.340
	(–0.54)	(1.02)	(–1.57)	(1.70)
FoF fixed effects	No	No	Yes	Yes
Observations	988	500	988	500
R-squared	0.007	0.051	0.108	0.222