CFR Working Paper NO. 15-12

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

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AUGUST 2015

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

The 2007-2009 financial crisis triggered a wave of regulatory and investor scrutiny relating to the traditional activities of banks and other financial intermediaries. Of particular interest are balance sheet mismatches in which short-term, liquid liabilities are used to fund long-term, illiquid assets. While such liquidity transformation is often viewed as a core function of financial intermediation, the recent crisis demonstrates that excessive liquidity mismatches can lead to investor runs and distressed asset sales that threaten an institution's solvency and, more seriously, the financial system.[1] Despite its importance, research in this area is challenging given the difficulty of measuring the liquidity of an institution's balance sheet which, for example, may depend on estimates of the impact that a distressed sale would have on an illiquid asset's cash value.

In this article, we overcome such challenges by studying and providing new insight on the extent and impact of liquidity mismatches in an important segment of the asset management industry – namely, registered funds of hedge funds (FoFs). 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).[2] An important advantage of our setting is that the liquidity of assets (underlying funds) and liabilities (FoF itself) are measured in the same units – that is, the permitted frequency of investor redemptions. In addition, the information about redemption terms on both the asset and liability sides of FoFs is

[1] See, e.g., Admati and Hellwig (2013) for a discussion of the banking system during the financial crisis.
[2] 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).

mandatorily reported and directly observable from the regulatory filings. This allows us to study the effects of liquidity mismatches on FoFs themselves as well as their underlying hedge fund investments.

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 of the liquidity mismatches for FoF investors? For example, 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? In addition, are FoFs with greater liquidity mismatches more vulnerable to investor runs, as would be evident by a greater sensitivity of investor flows to poor performance? Finally, do liquidity mismatches limit a FoF's access to best performing ("star") liquid hedge funds that 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?

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 FoFs themselves (liabilities). 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.

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 74% of the liquid best-performing hedge funds in the FoF portfolios are sold compared to only 30% 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- and liquidity-adjusted returns to benchmark fund performance, we uncover cumulative underperformance of 3.20%

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. 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 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 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 1.3% per one standard

deviation increase in the fitted value of illiquidity gap from the first stage. However, this relation turns negative during crisis periods when a similar increase in illiquidity gap is associated with a 1.6% *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.

Our final 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 one-standard-deviation increase in illiquidity gap is associated with a 33% decrease in the odds of FoF investment 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.

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 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.[3] 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.[4] Based on our evidence, at least part of this "illiquidity premium" can be explained by liquid funds being adversely affected by the

[3] Evidence of institutional price pressure is found in U.S. equity markets (Coval and Stafford, 2007; Hau and Lai, 2012; Aragon and Strahan, 2012; Tang, 2013; 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), Brunnermeier and Pedersen (2009), and Shleifer and Vishny (1992) present theoretical predictions on the effects of financial distress on asset values.

[4] 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.[5] 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, 2014, 2015) that studies the portfolio holdings of registered FoFs. Aiken, Clifford, and Ellis (2015) 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 (2014) 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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[5] 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).[6] 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 N-SAR filings. This helps us separate traditional closed-end funds from registered FoFs, whose shares are typically not exchange-traded. This yields 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 fund of funds (which should hold mutual funds or hedge funds) and mutual funds that invest directly in securities. This step allows us to remove 127 closed-end funds from 314 funds to leave us with 187 FoFs. We further filter the FoFs that invest in mutual funds and that are registered but never raise any capital, which leaves us with a

[6] While hedge funds have, historically, been restricted from advertising to the general public, these restrictions were lifted under the Jumpstart Our Business Startups (JOBS) Act of 2012.

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).[7] Finally, to augment any missing information from the regulatory filings in the two main data sources, we obtain performance, assets under management (AUM), and liquidity terms of the FoFs and their underlying hedge funds

[7] 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).

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) 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.[8]

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. 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. Therefore, funds with greater redemption restrictions represent the more illiquid assets held in a FoF's portfolio. The average range and standard deviation of hedge fund redemption restriction in a FoF portfolio are 331 and 104 days, respectively. These 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.[9]

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[8] 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).

[9] 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

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 the interquartile range covers a 59–day cushion to a 17–day "liquidity shortfall."

3. Selling decisions of funds of hedge funds

Unless a FoF can meet redemptions by using excess cash or new borrowing, it has no choice but to liquidate its hedge fund positions. To lay the groundwork for our subsequent analysis of flow-driven sales, we first examine whether investor outflows are indeed associated with a FoF's decision to divest from hedge funds. We also examine whether the liquidity and past performance of its hedge fund holdings influence a FoF's liquidation policy.

3.1 Flows into FoFs and changes in the FoF portfolios

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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.

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

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

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.[10]

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 of the FoF flows, and the fractions of the underlying hedge fund holdings that are reduced, eliminated, expanded, added, or maintained. Not surprisingly, we observe greater fractions of hedge funds that are 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:

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

[10] 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.

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.[11] 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 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 confirm our priors of the direction of the changes in FoF portfolios in response to FoF flows, i.e., expansions and reductions related to the inflows and outflows from FoFs, respectively.

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.

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

Table III reports the average change in holding of hedge funds sorted by their past performance and fund liquidity. We measure fund illiquidity and past performance using the fund's redemption restriction and prior quarter's benchmark-adjusted return,

[11] 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.

respectively. Along the liquidity dimension, funds are categorized into four groups based on whether the redemption frequency is less than or equal to monthly, greater than monthly but less than quarterly, greater than quarterly but less than semi-annually, and greater than semi-annually. We benchmark fund returns using the equally-weighted average returns of hedge funds that are held by registered FoFs in the quarter that are in the same hedge fund style category and have similar redemption restrictions as the sold funds. We only include positions that are eliminated, reduced, or maintained among the FoFs that experience negative flows.

The evidence reveals a strong tendency for FoFs to sell their most liquid positions. Moving down each column of Table III shows the amount of selling of funds across liquidity quartiles while holding past performance fixed. For example, among the worst performers (quartile 1), the average change in holding is –14.9% among the funds with the highest redemption restriction as compared to –24.6% among funds with the lowest redemption restriction (see Panel A of Table III). Poor performers seem to be able to spare themselves, to some extent, from being sold by FoFs by having greater redemption restrictions in place. A similar pattern holds for all but the very best performers (quartile 4), the group that FoFs would be most hesitant to sell regardless of their liquidity. [12]

The evidence also shows a tendency for FoFs to sell poorly performing funds, at least among liquid funds. For example, moving across the top row in Panel A of Table

[12] 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.

III, among funds with the lowest redemption restriction (Group 1), the average change in holding is –24.6% and –14.3% for the worst and best performers, respectively. The difference of 10.3% is both economically and statistically significant. 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, 2014). In contrast, among the most illiquid funds, we see virtually no relation between the amount of selling and past performance (figures of –14.9% and –15.6% for the worst and best past performers, respectively, in Group 4 of redemption restriction are not significantly different from each other). Taken together, these results suggest that FoF managers' preference of selling poor past performers is constrained by the redemption restriction imposed by the underlying funds.[13]

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 (–14.3%) is about the same as that of the worst performers with the highest redemption restriction (–14.9%). 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 of Table III shows the selling activities of the FoFs that experience extreme outflows (i.e., flows in the bottom fifth percentile). Strikingly, the best performers with the lowest redemption restriction are sold more than the worst performers that impose the

[13] One possible concern is that FoFs perceive illiquid funds as better investments, and are therefore less inclined to sell such funds. However, this seems unlikely to explain our findings because in untabulated results, we do not find that FoFs experiencing *inflows* invest more in illiquid funds.

highest redemption restriction. The change in holding of the best performers with the lowest redemption restriction is –74.2%, which is 43.9% significantly greater than that of the worst performers with the highest redemption restriction (–30.3%). These findings demonstrate that even *best-performing* liquid funds are sold by distressed FoF that experience extreme outflows.

3.2.2. Multivariate analysis of FoF selling decisions

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 hedge funds with low (below median) and high (above median) redemption restriction. In Models 1 to 4 of Table IV, the dependent variable is *change in holding*, i.e., the percentage 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 (0.320; *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 0.32 implies that the worst performer in the portfolio is sold more than the best performer by 32% of the shares held in the prior quarter. In contrast, the coefficient of –0.001 on past performance is insignificant in Model 2 when we focus on the funds with high redemption restrictions. The difference of –0.321 in the coefficients on past performance between the low and high redemption restriction funds is highly significant. This is consistent with our earlier evidence that FoFs' preference of selling poor past performers are constrained by the illiquidity of the underlying funds.

The coefficient of 0.856 (0.499) 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 43% (25%) of the shares held. The coefficient is significantly lower by 0.357 for the funds with high redemption restrictions. We find similar results in Models 3 and 4 when the FoF and quarter fixed effects are included. We also find qualitatively similar results when we estimate pooled regressions with interaction variables using the full sample rather than splitting the sample by redemption restriction. Overall, these findings corroborate our earlier results in Table III which suggests that flow-driven selling is attenuated by the illiquidity of the funds in FoF portfolios.

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

Our findings from the previous section show that liquid funds are likely targets of distressed selling by FoFs experiencing investor outflows. This could, in turn, lead to worse performance for the sold funds if divestments force funds into distressed selling of their own securities. We examine this issue by studying the future performance of hedge funds that are sold by distressed FoFs. We also examine whether these effects are magnified in the presence of larger liquidity mismatches as measured by FoF illiquidity gaps.

4.1. Ex-post performance of hedge funds sold by distressed FoFs

Our main hypothesis is that redemptions by distressed FoFs are likely to result in sold hedge funds to perform poorly, because these funds are forced into costly fire sales

of their underlying securities.[14] By conditioning our empirical tests on sales by FoFs that need liquidity, we focus on a quasi-exogenous shock to demand for hedge funds from FoFs that need liquidity. Therefore, there is a priori less reason to believe that sales of liquid funds (and poor post-sale performance) are information motivated. In other words, 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. Nevertheless, we further distinguish between these two motives by conducting a battery of tests on sold funds after dividing them into sub-samples based on their exposure to the distressed sales by FoFs.

The premise of our first empirical test is that liquid funds are more exposed to the distressed selling of FoFs. Liquid funds have to sell assets in a shorter period of time to meet investor redemptions, while funds with high redemption restrictions can liquidate securities in an orderly fashion and avoid distressed sales. Therefore, if FoFs cause hedge funds to engage in distressed sales, the poor post-sale performance will be concentrated among liquid funds. The negative effect of distressed selling by FoFs on fund performance should be weakened, if not eliminated, by redemption restrictions. Alternatively, 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 liquid and illiquid fund subsamples.

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.

[14] Ben-David, Franzoni, and Moussawi (2012) and Boyson, Helwege, and Jindra (2013) provide evidence on fire sale of stocks held by hedge funds.

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 then compute post-event cumulative benchmark-adjusted returns (CARs) for each fund in a distressed sale.

Table V shows the quarter-by-quarter average CAR over the eight quarters following a distressed sale. The portfolio of funds is rebalanced each quarter. As shown in Panel A, the sold funds with low redemption restrictions (less than or equal to 31 days) have negative CARs for all quarters after the distressed sales. For example, we estimate that sold funds have underperformance of –3.20% (p-value<0.05) through fourth quarter following the event. The CAR estimates are significant at conventional levels with the exception of quarter 1 (t-stat = –1.60) and the more distant quarters. In contrast, 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.[15]

Recall that our benchmark returns are based on the average return of a peer group

[15] 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.

that matches the style category and redemption restriction of each fund. Therefore, our abnormal returns are unlikely to be affected by differences in liquidity premium or average returns across liquid and illiquid fund groups. Moreover, note that the post-sale fund underperformance of liquid funds is partially reversed as we move further out past the event date; in fact, none of the CARs are significant following the fifth quarter. This is consistent with the *temporary* "fire-sale" effects documented in prior studies of security-level returns (e.g., Coval and Stafford, 2007).[16] If, on the other hand, the underperformance is due to information about the fundamentals underpinning the fund's strategy, we would expect the CARs to persist.

4.2. Do liquidity mismatches magnify the effects?

The above evidence shows that the costs of distressed sales are borne by liquid hedge funds. We expect these effects to be magnified among liquid funds that are held by FoFs with a greater illiquidity gap and, therefore, few alternative sources of liquidity from which to raise cash. In the event of outflows, these FoFs would exert greater selling pressure on the few liquid funds that they do hold.

The evidence in Panel B of Table V shows that the subsequent underperformance of liquid funds is indeed greater among funds that are sold by FoFs with a high (above-median) illiquidity gap, as compared to those held by FoFs with a low illiquidity gap. For example, the average CAR is –6.54% through four quarters (p-value<0.05) for the high illiquidity gap subsample, as compared to an insignificant –0.66% for funds sold by

[16] Ozik and Sadka (2014) note that the temporary effects on security prices resulting from fire sales may lead to permanent effects on fund performance 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.

low illiquidity gap FoFs. This difference is statistically significant at conventional levels (*t*-stat = –2.00). We interpret this as further evidence that the liquidity-motivated redemptions of FoFs cause sold funds to underperform benchmarks.

Throughout our analysis, we recognize that the illiquidity gap results from the liquidity choices (for assets and liabilities) made by the FoFs. Therefore, we account for the endogenous nature of illiquidity gap by modeling its determinants based on observable fund characteristics. Based on the fitted values of illiquidity gap from a first-stage regression (Model 2 of Table VI, discussed in the following section), Panel C of Table V confirms our earlier findings that the post-sale underperformance of liquid funds sold in distress is concentrated among funds that are sold by FoFs with greater illiquidity gaps. Taken together, based on our results in this section, we conclude that liquidity mismatches in FoFs exacerbate the effects of distressed sales on its hedge fund investments.

5. Impact of asset-liability liquidity mismatches on FoFs

5.1. How does illiquidity gap affect FoF performance?

Our analysis thus far shows that distressed sales by FoFs impose significant costs on the sold funds, especially among funds that are sold by FoFs with greater liquidity mismatches. To the extent that FoFs internalize the costs from distressed sales, a higher illiquidity gap predicts worse FoF performance during market conditions where investor outflows and, hence, distress, would be most severe. Therefore, we expect that FoFs with

larger illiquidity gaps should exhibit better performance during normal times but perform worse during a crisis.[17]

Table VI reports the results from a regression of quarterly FoF returns on lagged illiquidity gap and several fund characteristics. The key variables are illiquidity gap and its interaction with a dummy that equals one for all quarters covering the financial crisis period. The evidence in Model 1 provides some support for our hypothesis. For example, we find that a one standard deviation increase in illiquidity gap (72.4 days) is associated with 0.55% lower quarterly FoF returns during the crisis period (*t*-stat = –1.73). A higher illiquidity gap is also associated with higher FoF returns outside the crisis period, though the coefficient is not significant.

The endogenous nature of illiquidity gaps can make it difficult to identify their effects on liquidity risk in FoF returns. This would be the case if FoFs with higher illiquidity gaps are inherently less exposed to investor runs during a crisis. Therefore, we follow a two-stage least squares (2SLS) to study the causal relation between illiquidity gap and FoF performance. 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

[17] 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.

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 VI reports the results of the 2SLS procedure. Model 2 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. Model 3 reports the results from the second stage. Specifically, we regress a FoF's quarterly returns on the predicted (i.e., fitted) 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. = 0.0448; *t*-stat = 3.56) 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 *fitted* illiquidity gap of 28.8 days is associated with 1.3% greater quarterly returns. The interaction of crisis indicator variable and illiquidity gap is negative and statistically significant (coeff. = –0.0547; *t*-stat = –2.72). 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 1.6% *lower* quarterly

returns. Overall, the results from the second stage provide strong support for our hypothesis that liquidity mismatches are associated with greater funding liquidity risk in FoFs.

5.2. 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, 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 during a crisis period. For this purpose, we regress quarterly FoF flows estimated through equation (2) on the prior quarter's returns, illiquidity gap, and an interaction of the returns and illiquidity gap. We control for several FoF characteristics. The standard errors are clustered at the quarter level. Our main variable of interest is the interaction between the return component and illiquidity gap during the crisis period. Theories of strategic complementarities predict a positive coefficient on this interaction variable, which would indicate a greater sensitivity of flows among FoFs with greater illiquidity gaps. In contrast, we do not expect heightened flow-performance sensitivity in the presence of higher illiquidity gaps during

the non-crisis period, since investors would not anticipate adverse effects from liquidity mismatches.

Our results are reported in Table VII and are consistent with the theoretical predictions. Specifically, the interaction term between past returns and illiquidity gap is positive (coeff. = 0.260) and significant (*t*-stat = 2.52) during the crisis period (Model 1). In addition to being statistically significant, these findings are economically meaningful. For example, we estimate that a drop in returns from 0% to –10% is associated with a 4.17% decrease in quarterly flows, among FoFs with no illiquidity gap. This is consistent with existing evidence of a positive flow-performance relation in hedge funds (e.g., Agarwal, Daniel, and Naik, 2006; Brown et al., 2008; Getmansky et al., 2010). However, a one standard deviation increase in illiquidity gap would lead to a further 1.88% decline in investor flows. Model 3 reports the results during non-crisis period. In contrast to our findings for the crisis period, we find no evidence that liquidity mismatches in FoFs increase the sensitivity of investor flows to past performance.

Models 2 and 4 of Table VII report stronger results when we use the fitted values from a regression of illiquidity gap on fund characteristics in the first stage described earlier. In particular, following a drop in returns from 0% to –10%, a one standard deviation increase in fitted illiquidity gap is associated with a 3.87% (= 28.8 days x 1.344 x 10%) lower flows, as compared to a FoF with zero fitted illiquidity gap. In contrast, we find no significant interaction between past performance and fitted illiquidity gap during the non-crisis period (Model 4). Overall, this evidence suggests that greater liquidity mismatches can lead to runs that further amplify the funding liquidity risk in FoFs.

5.3. Do liquid star hedge funds avoid FoF investments?

Our earlier results 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.[18]

To test this hypothesis, we use logistic regressions to study whether illiquidity gaps reduce a FoF's ability to add liquid star funds to its portfolio. Specifically, our key dependent variable is an indicator variable that equals one if at least one liquid star fund is added to the FoF's portfolio during the quarter. The illiquidity gap of the same FoF in the prior quarter is the key independent variable in this regression. We include all independent variables in Model 2 of Table VI as control variables. Standard errors are clustered at the quarter level. To be included in the regression, we require each FoF to have added at least one liquid fund (star or non-star) during the quarter. We likewise estimate the regression using the FoF's new investments in star illiquid hedge funds. We

[18] 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.

define star funds as the top 10% performers, where performance is measured using benchmark-adjusted fund returns (i.e., based on the returns of peer funds with the same style category and similar redemption restrictions) in the prior year. 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 31 days.

We report the results in Table VIII. Models 1 and 3 correspond to results for liquid and illiquid star funds, respectively. As shown in Model 1, the coefficient on lagged illiquidity gap is negative and statistically significant, which suggests that liquid star funds are less likely to be added to a FoF's portfolio when these FoFs have larger illiquidity gaps. Specifically, we find that a one-standard-deviation increase in illiquidity gap is associated with a 33% (=1 – exp(-0.549 x 0.7241)) decrease in the odds of FoF investment in star liquid funds. Furthermore, in Model 3 we find that illiquidity gaps are not significantly related to a FoF's propensity to add star illiquid hedge funds to its portfolio. Models 2 and 4 reveal similar findings when we repeat the analysis using the fitted values from a regression of illiquidity gap on fund characteristics.

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.

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.[19]

We also 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. Furthermore, 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. Finally, our findings suggest that FoFs 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-

[19] 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).

performing funds with lower redemption restrictions due to liquidity shortfalls elsewhere in the FoF's portfolio. 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 selling decisions of FoFs (double sort)

This table reports the average change in holding for each hedge fund group sorted by hedge funds' past performance (measured as benchmark-adjusted return during the prior quarter) and redemption restriction. Along the liquidity dimension, funds are categorized into four groups based on whether the redemption frequency is less than or equal to monthly, greater than monthly but less than quarterly, greater than quarterly but less than semi-annually, and greater than semi-annually. We benchmark fund returns using the equal-weighted average returns of hedge funds that are held by registered FoFs in the quarter that are in the same hedge fund style category and have similar redemption restrictions as the sold funds. 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)

		Past Performance				
		1 (Worst)	2	3	4 (Best)	Difference (4–1)
Redemption restriction	1 (Lowest)	–24.56	–16.21	–16.39	–14.26	10.3****
	2	–19.78	–13.31	–13.16	–15.39	4.39****
	3	–14.15	–12.73	–11.04	–16.17	–2.02
	4 (Highest)	–14.92	–11.6	–12.85	–15.56	–0.64
	Difference (4–1)	9.64****	4.61**	3.54*	–1.3	
	Difference (14–41)	0.66				

Panel B. Bottom fifth percentile flows (extreme outflows)

		Past Performance				
		1 (Worst)	2	3	4 (Best)	Difference (4–1)
Redemption restriction	1 (Lowest)	–91.13	–73.57	–61.44	–74.2	16.93
	2	–49.53	–50.58	–37.68	–58.36	–8.83
	3	–43.75	–40.7	–12.24	–39.8	3.95
	4 (Highest)	–30.32	–26.8	–19.87	–37.72	–7.4
	Difference (4–1)	60.81****	46.77****	41.57**	36.48**	
	Difference (14–41)	–43.88***				

Table IV: 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 past performance (measured as benchmark-adjusted return during the prior quarter) of underlying hedge funds in FoF portfolios. We benchmark fund returns using the equal-weighted average returns of hedge funds that are held by registered FoFs in the quarter that are in the same hedge fund style category and have similar redemption restrictions as the sold funds. 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 (less or equal to 31 days) and high (greater than 31 days) redemption restrictions. Models 3 and 4 include FOF and quarter fixed effects. 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					
	Redemption restriction					
	Low (<=31 days)	High (>31 days)	Difference	Low(<=31 days)	High (>31 days)	Difference
	(1)	(2)		(3)	(4)	
Past performance	0.320****	–0.001	–0.321**	0.272***	0.00122	–0.271**
	(4.09)	(–0.01)		(3.50)	(0.02)	
FoF flow	0.856****	0.499****	–0.357****	0.766****	0.422****	–0.344****
	(8.63)	(4.24)		(9.91)	(6.36)	
Constant	–0.0988****	–0.104****		0.0104	–0.220	
	(–7.58)	(–11.20)		(0.71)	(–1.10)	
Observations	1949	8068		1949	8068	
R-squared	0.136	0.049		0.240	0.097	
Quarter FE	No	No		Yes	Yes	
FoF FE	No	No		Yes	Yes	

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

This table reports the cumulative average 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. We benchmark fund returns using the equal-weighted average returns of hedge funds that are held by registered FoFs in the quarter that are in the same hedge fund style category and have similar redemption restrictions as the sold funds. In Panel A, the cumulative average abnormal returns are reported for the sub-samples with low and high redemption restrictions. In Panel B and C, the sold hedge funds with low redemption restrictions are further divided into two subsamples based on the original and fitted value of illiquidity gap of the FoFs, respectively. 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 Average Abnormal Returns							
	1 quarter	2 quarters	3 quarters	4 quarters	5 quarters	6 quarters	7 quarters	8 quarters
Low redemption restriction (<=31 days)								
	–0.0083	–0.0195**	–0.0209*	–0.0320**	–0.0390**	–0.0305	–0.0244	–0.0240
	(–1.60)	(–2.01)	(–1.79)	(–2.32)	(–2.30)	(–1.63)	(–1.20)	(–1.03)
High redemption restriction (>31 days)								
	–0.0022	–0.0033	0.0035	–0.0022	–0.0080	–0.0041	–0.0075	–0.0039
	(–0.55)	(–0.47)	(0.32)	(–0.22)	(–0.59)	(–0.31)	(–0.44)	(–0.29)
Difference (Low–High)								
	–0.0061	–0.0162	–0.0244*	–0.0298*	–0.0310	–0.0265	–0.0168	–0.0202
	(–0.89)	(–1.37)	(–1.72)	(–1.78)	(–1.55)	(–1.20)	(–0.70)	(–0.74)

Panel B. High vs. low illiquidity gap

	Cumulative Abnormal Returns						
1 quarter	2quarters	3quarters	4 quarters	5 quarters	6 quarters	7 quarters	8 quarters
High Illiquidity Gap (above median)							
–0.0071	–0.0356*	–0.0399*	–0.0654**	–0.0896**	–0.0690**	–0.0501	–0.0526
(–0.93)	(–1.91)	(–1.87)	(–2.76)	(–3.00)	(–2.07)	(–1.37)	(–1.31)
Low Illiquidity Gap (below median)							
–0.0056	–0.0053	–0.0107	–0.0066	0.0007	–0.0010	–0.0041	0.0078
(–0.75)	(–0.47)	(–0.74)	(–0.38)	(0.03)	(–0.04)	(–0.17)	(0.27)
Difference (High–Low)							
–0.0015	–0.0303	–0.0292	–0.0588**	–0.0903**	–0.0680*	–0.0460	–0.0604
(–0.14)	(–1.39)	(–1.13)	(–2.00)	(–2.49)	(–1.69)	(–1.06)	(–1.23)

Panel C. High vs. low illiquidity gap (fitted gap)

	Cumulative Abnormal Returns						
1 quarter	2 quarters	3 quarters	4 quarters	5 quarters	6 quarters	7 quarters	8 quarters
High Illiquidity Gap (above median)							
–0.0055	–0.0171	–0.0250*	–0.0417**	–0.0647**	–0.0560**	–0.0424	–0.0434
(–0.69)	(–1.46)	(–1.74)	(–2.31)	(–2.65)	(–2.04)	(–1.4)	(–1.29)
Low Illiquidity Gap (below median)							
–0.0092	–0.0236	–0.0133	–0.0068	0.0056	0.0242	0.0164	0.0412
(–0.96)	(–1.14)	(–0.55)	(–0.24)	(0.17)	(0.66)	(0.43)	(1.01)
Difference (High–Low)							
0.0037	0.0066	–0.0118	–0.0349	–0.0703*	–0.0802*	–0.0588	–0.0846
(0.3)	(0.28)	(–0.42)	(–1.04)	(–1.72)	(–1.76)	(–1.2)	(–1.6)

Table VI: Illiquidity gap and FoF performance

This table reports the results from regressing quarterly FoF returns on lagged illiquidity gap. In Model 1 we use the original illiquidity gap variable defined in Table I. Models 2 and 3 report the results from a two-stage least squares (2SLS) regressions. First stage (2) 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 FoF returns (*lagged FOFreturn*), investor flows (*lagged FoFflow*), assets under management (*lagged logFoFsize*), age (*lagged logFoFage*), management fee (*lagged managementfee*), and incentive fee (*lagged incentivefee*). Second stage (3) regresses FoF quarterly returns on the first-stage predicted illiquidity gap, an indicator variable for crisis (*crisis dummy*), and the interaction of the two. Models 1-3 include 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	Second stage
	FoF returns	lagged Illiquidity gap	FoF returns
	(1)	(2)	(3)
Lagged illiquidity gap	0.00206		
	(0.97)		
Lagged illiquidity gap x crisis dummy	–0.00759*		
	(–1.73)		
Fitted values of lagged illiquidity gap from the first stage			0.0448***
			(3.56)
Fitted value of lagged illiquidity gap x crisis dummy			–0.0547**
			(–2.72)
Lagged FoFreturn	0.00587	1.332	–0.0574
	(0.04)	(1.07)	(–0.44)
Lagged FoFflow	0.00192	0.107*	–0.00285
	(1.04)	(1.84)	(–0.99)
Lagged logFoFsize	0.00104	0.0625***	–0.00216
	(0.77)	(3.62)	(–1.27)
Lagged logFoFage	–0.00742	–0.350****	0.00660
	(–0.99)	(–10.30)	(1.00)
Lagged managementfee	0.00687	–0.236***	0.0179*
	(0.96)	(–2.99)	(2.03)
Lagged incentivefee	0.000738	0.0230****	–0.000191
	(0.99)	(4.45)	(–0.28)
Log company size at inception date		0.0329****	
		(5.49)	
Crisis dummy & its interactions with fund characteristics	Yes	Yes	Yes
Constant	0.0149	–0.517**	0.0224
	(0.65)	(–2.30)	(0.93)
Observations	907	907	907
R–squared	0.116	0.149	0.116

Table VII: Illiquidity gap and flow-performance sensitivity

This table reports the results of regressing quarterly FoF flows on the prior quarter's returns, illiquidity gap, and an interaction of the returns and illiquidity gap during the crisis and non-crisis periods. Models 1 and 3 use the original illiquidity gap; Models 2 and 4 use the fitted values of illiquidity gap from Table VI. Control variables include investor flows, assets under management, age, management fee, and incentive fee. Standard errors are clustered at the quarter level. *, **, ***, and **** denote statistical significance at 10, 5, 1, and 0.1 percent level, respectively.

	Crisis		Non-Crisis	
	Original	Fitted	Original	Fitted
	(1)	(2)	(3)	(4)
Lagged illiquidity gap	–0.00308	0.0561	0.0402*	0.612
	(–0.24)	(0.75)	(1.79)	(1.56)
Lagged illiquidity gap x lagged FOFreturn	0.260**	1.344***	0.628	–2.474
	(2.52)	(3.60)	(0.53)	(–0.94)
Lagged FOFreturn	0.417*	0.638***	0.359	–0.983
	(1.80)	(3.55)	(0.52)	(–1.29)
Lagged FoFflow	0.172**	0.207*	–0.0354	–0.0613
	(2.49)	(2.16)	(–0.41)	(–0.47)
Lagged logFoFsize	0.0287**	0.0163	–0.0232	–0.0583
	(2.99)	(1.18)	(–0.64)	(–0.98)
Lagged logFoFage	–0.108****	–0.0550	–0.0373	0.139
	(–4.57)	(–0.81)	(–1.30)	(0.98)
Lagged managementfee	0.0192	0.0165	0.0356	0.184
	(0.72)	(0.55)	(1.16)	(1.74)
Lagged incentivefee	0.00428*	0.00378	–0.00473	–0.0150
	(2.02)	(1.75)	(–1.04)	(–1.33)
Constant	–0.161	–0.121	0.598	0.583
	(–0.88)	(–0.80)	(0.91)	(0.94)
Observations	406	406	501	501
R–squared	0.164	0.177	0.031	0.032

Table VIII: Illiquidity gap and FoF investments in star funds

This table reports the results of logit regressions where dependent variable equals 1 if at least one liquid star fund is added to the FoF's portfolio during the quarter, otherwise 0. To be included in the regression, we require each FoF to have added at least one liquid fund (star or non-star) during the quarter. We likewise estimate the regression using the FoF's new investments in star illiquid hedge funds. We define star funds as the top 10% performers, where performance is measured using benchmark-adjusted fund returns (i.e., based on the returns of peer funds with the same style category and similar redemption restrictions) in the prior year. Liquid funds are the funds with a redemption frequency of less than or equal to 31 days and illiquid funds are funds with redemption restriction of greater than 31 days. Models 1 and 3 use the original illiquidity gap; Models 2 and 4 use the fitted values of illiquidity gap from Table VI. 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		Illquid star funds	
	Original	Fitted	Original	Fitted
	(1)	(2)	(3)	(4)
Lagged illiquidity gap	–0.549**	–4.112*	–0.166	1.452
	(–2.12)	(–1.89)	(–0.85)	(0.84)
Lagged FOFreturn	3.749	7.659	9.547***	7.587**
	(0.60)	(1.00)	(2.60)	(2.26)
Lagged FOFflow	–1.324	–1.083	–0.384	–0.561
	(–1.00)	(–0.74)	(–1.06)	(–1.40)
Lagged logFOFsize	0.0795	0.323	–0.0746	–0.185
	(0.49)	(1.19)	(–0.53)	(–1.24)
Lagged logFOFage	–0.926***	–2.155**	0.281	0.845
	(–2.80)	(–2.51)	(1.03)	(1.39)
Lagged managementfee	–1.024	–2.099**	1.292**	1.749**
	(–0.99)	(–2.22)	(2.42)	(2.17)
Lagged incentivefee	0.00123	0.0588	0.0227	–0.00867
	(0.01)	(0.56)	(0.54)	(–0.16)
Crisis dummy & its interactions with fund characteristics	Yes	Yes	Yes	Yes
Constant	0.956	1.306	–3.408	–3.533
	(0.25)	(0.34)	(–1.22)	(–1.21)
Observations	295	295	558	558

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