Dynamic Liquidity Management by Corporate Bond Mutual Funds *

Hao Jiang†
Michigan State University

Dan Li‡
Board of Governors of the Federal Reserve System

Ashley W. Wang§
Board of Governors of the Federal Reserve System

First Draft: September 2015
This Version: October 2017

*The views presented here are solely those of the authors and do not represent those of the Federal Reserve Board or its staff. We thank Patrick Bolton, Chris Clifford (discussant), Xuewen Liu, Claudio Raddatz (discussant), and conference and seminar participants at 2017 Asset Management Conference ESMT Berlin, 2017 Financial Stability Board Analytical Group on Vulnerabilities Workshop, China Europe International Business School, Federal Reserve Board, SEC, Tsinghua University and University of Hong Kong.

†Tel.: (517) 353-2920; e-mail: jiangh@broad.msu.edu.
‡Tel.: (202) 452-2626; e-mail: dan.li@frb.gov.
§Tel.: (202) 452-3122; e-mail: ashley.wang@frb.gov.

Abstract

Corporate bond mutual funds tend to hold illiquid assets but provide liquid claims to their investors. How do they manage liquidity to meet investor redemptions? We show that, during tranquil market conditions, these funds tend to reduce liquid asset holdings such as cash and government bonds to meet investor redemptions, temporarily increasing their relative exposures to illiquid asset classes. During periods with heightened aggregate uncertainty, however, they tend to scale down their liquid and illiquid asset proportionally, thereby preserving the liquidity of their portfolios. This fund-level dynamic management of liquidity appears to impact the broad financial market: flows-induced trades in corporate bonds by these funds during high-uncertainty periods generate price pressures, which precede strong return reversals.

JEL Classification: G10, G23

Key words: Liquidity, Mutual funds, Corporate Bond Funds, Run Risk, Fire Sales

1 Introduction

The asset management industry has played an increasingly important role in the financial system. The International Monetary Fund (IMF) reported in 2015 that the top 500 largest asset managers intermediated $76 trillion of assets, which accounted for 100% of the world GDP and 40% of the global financial assets. Against the backdrop of a post-crisis shift in credit intermediation from the banking sector to the asset management industry, an increasing fraction of corporate debt is held by open-end mutual funds, which allow their investors to redeem their shares on a daily basis. This daily redeemability, coupled with the illiquidity of corporate debt they hold, effectively leads to liquidity transformation.

However, the liquidity transformation comes with its own risks. Indeed, significant outflows were observed from bond funds accompanied by elevated market volatility over recent events, including the 2013 Taper Tantrum and the 2015 Third Avenue Focused Credit Fund's suspension of redemptions. Such events highlighted the concern that the liquidity mismatch in the mutual fund industry might threaten financial stability. In light of these developments, regulators have continued to strengthen oversight of the asset management industry. For instance, the Securities and Exchange Commission (SEC) has adopted new rules since October 2016 to strengthen liquidity management programs for open-end mutual funds; the Financial Stability Board set out in 2017 several policy recommendations regarding the disclosure and implementation of liquidity risk management programs for open-end mutual funds.[1]

Despite the intensified interest in understanding potential risks to financial stability due to investor flows, relatively little is known about liquidity management practices of asset managers. In particular, how do asset managers meet investor redemptions? Do they use different strategies to accommodate investor redemptions under different market conditions? Do different managers follow different practices? What are the implications of micro-level liquidity management practices for the pricing and stability of the broad financial markets? In this paper, we shed light on these questions with a focus on liquidity management at open-end corporate bond mutual funds.

Corporate bond funds provide an interesting setting to study liquidity management by asset

[1] See, `https://www.sec.gov/rules/final/2016/33-10233.pdf` and `http://www.fsb.org/wp-content/uploads/FSB-Policy-Recommendations-on-Asset-Management-Structural-Vulnerabilities.pdf`, respectively.

managers, as they provide liquidity transformation by allowing daily redemptions while investing in relatively illiquid corporate debt.[2] As a result, effective liquidity management is critical to the smooth operation and performance of these funds. Moreover, recent studies such as Goldstein, Jiang, and Ng (2017) highlight how the illiquidity of corporate bonds can lead to a first mover advantage among corporate bond fund investors in their redemption decisions, which generates run risks on these funds. In this context, it is of interest to study whether and how liquidity management by corporate bond funds takes into account the potential run risk, which allows us to better understand the implication of fund-level liquidity management for the pricing of securities and stability of broad financial markets.

Using detailed holding data on a panel of 578 open-end actively managed corporate bond funds from 2002 to 2014, we investigate fund-level liquidity management practices upon investor redemptions. Our analyses generate several key results. First, in response to investor redemptions, managers of corporate bond funds, on average, tend to reduce their liquid asset holdings such as cash and government bonds which results in increased relative exposures to illiquid asset classes such as corporate bonds. In other words, corporate bond funds tend to consume liquid assets, horizontally cutting their assets along the liquidity spectrum to meet investor redemptions, a practice we refer to as a "horizontal cut." Exploiting cross-sectional heterogeneity, we find that corporate bond funds with lower funding uncertainty, less persistent flows, and lower rear-end loads exhibit a stronger tendency to follow such a horizontal cut approach.

Second, the strategy to meet investor redemptions appears to be contingent on market conditions. In particular, we find that when aggregate uncertainty, as captured by the CBOE volatility index (VIX), is above its historical median, corporate bond funds are less willing to pursue a "horizontal cut" of their portfolios, but are tilted toward a "vertical cut" of their assets. In this situation, they tend to scale down their assets, maintaining their allocations between liquid and illiquid asset classes and thereby preserving the liquidity of their portfolios. The reluctance of corporate bond funds to consume liquid assets to meet investor redemptions during the high-uncertainty period points to funds' aversion to increased vulnerabilities arising from holding illiquid assets.

In combination, these two results on asset allocations suggest that corporate bond fund managers

[2] Previous literature on liquidity transformation mainly focuses on banks and shadow banking such as money market funds. See for example, Diamond and Dybvig (1983), Gorton and Pennacchi (1990), and Gorton and Metrick (2010).

tend to trade off between short-term liquidation costs that might jeopardize the near-term fund performance, and longer-term vulnerabilities arising from excess tilts toward illiquid assets that might threaten future fund viability.

Third, to shed light on the dynamics of liquidity management by corporate bond funds, we examine how their liquid asset holdings change following investor redemptions. If shocks to investor redemptions lead funds to deviate below their desired level of liquid asset holdings, fund managers may need to replenish liquidity reserves after the shocks abate. Indeed, we find that subsequent to investor redemptions, corporate bond funds tend to increase their holdings of liquid assets such as cash and government bonds. The increase in liquid asset holdings is larger during periods of heightened aggregate uncertainty. These results are consistent with corporate bond funds dynamically managing their asset mix to restore portfolio liquidity towards their target, following redemption-induced portfolio deviations.

Fourth, we examine how corporate bond funds liquidate individual corporate bonds to meet investor redemptions. Our results indicate that corporate bond funds tend to follow a "liquidity pecking order," selling liquid corporate bonds first to meet investor redemptions.

Fifth, we investigate whether corporate bond fund managers respond differently to expected and unexpected redemptions. We show that they tend to rely more on cash and liquid assets to meet unexpected investor redemptions, but scale down their assets more proportionally across asset classes to accommodate expected redemptions. This finding illustrates the important role of liquidity in meeting mutual fund contingent needs, which resonates with the central theme in the literature on precautionary motives for cash holdings. We also find that the liquidity pecking order in bond liquidation is more important for fund managers with large unexpected outflows.

These results paint a picture of corporate bond fund managers dynamically managing liquidity at the level of individual funds, which has interesting implications. First, the practice of using liquid assets to meet investor redemptions and then conducting costly trades in corporate bonds to restore liquid holdings represents a mechanism that leads to a first-mover advantage among investor redemptions, which amplifies the risk of runs (Stein, 2014; Goldstein, Jiang, and Ng, 2017). Thinking about financial stability, a caveat here is that the practice of a horizontal cut tends to be prevalent in tranquil markets, over which the risks of future fire sales of illiquid assets and the resulting adverse market impact may be limited. Second, the behavior of fund managers switching to a vertical cut and shrinking their asset holdings more on a pro-rata basis amid heightened aggregate uncertainty may weaken the incentives for runs on individual funds. However, its efficacy is likely to be limited, because at times of elevated aggregate uncertainty, liquidating corporate bonds may incur a higher transaction cost, particularly when other funds choose to sell corporate bonds at the same time. Moreover, the common tendency of corporate bond funds to liquidate corporate bonds in response to investor redemptions during periods with high uncertainty may lead to a particularly high demand for liquidity in the corporate bond market. Considering the increased reluctance of liquidity providers to supply liquidity when volatility rises (Nagel, 2012), corporate bond fund trading can generate a significant impact on the prices of corporate bonds in this situation.

Our last set of analyses examines this conjecture. Using both panel regressions and portfolio sorts, we show that corporate bonds subject to higher trading pressure (Coval and Stafford, 2007) from corporate bond funds exhibit stronger subsequent return reversals. Such a return reversal is particularly prominent at times of elevated aggregate uncertainty, when mutual funds tend to maintain portfolio liquidity by liquidating corporate bonds to meet investor redemptions. This result indicates that the micro-level liquidity management practices by mutual funds may have unintended consequences for the broad financial markets during periods of market stress.

Our paper contributes to the growing literature on financial fragility and run-like behavior among investors in open-end mutual funds (e.g., Chen, Goldstein, and Jiang, 2010; Feroli et al., 2014; Goldstein, Jiang, and Ng, 2017; and Zeng 2015). This literature shows that when a mutual fund holds illiquid assets, the negative externality of investor redemptions on remaining shareholders can generate a first-mover advantage, leading to self-fulfilling investor runs and potentially imposing financial fragility. However, it remains an open empirical question how mutual fund managers behave in the presence of first-mover advantages. By addressing this important question, our study helps to improve our understanding on the interaction between fund managers' liquidity management and the behavior of fund investors and on the potential sources that threaten financial stability.

Our paper is naturally connected to the literature on liquidity management by asset managers. There is a large literature that studies the decisions of mutual funds to hold cash and liquid assets.[3]

[3]See, e.g., Yan (2006), Simutin (2014), Huang (2015), Fulkerson and Riley (2015), and Hanouna, Novak, Riley, and Stahel (2015).

Our paper differs in focusing on fund managers' strategies to meet investor redemptions and how their asset liquidation strategies interact with fund investors and influence the broad financial market. Liu and Mello (2011) develop a model linking the behavior of hedge fund managers hoarding liquid assets during a financial crisis to concerns of coordination risk of hedge fund investor redemptions. Their theory has useful implications for our empirical work, although their focus is on hedge funds with lock-up and other redemption restrictions. Chernenko and Sunderam (2016) study the role of cash holdings in meeting investor redemptions for both U.S. equity and bond funds. Shek, Shim and Shin (2015) and Morris, Shim and Shin (2017) examine how emerging market bond funds manage redemption-induced and discretionary sales of bond holdings. Whereas Chernenko and Sunderam (2016) find that fund managers tend to use cash to absorb the influence of investor flows, Shek, Shim and Shin (2015) and Morris, Shim and Shin (2017) find that emerging market bond fund managers tend to hoard cash, selling illiquid assets to increase their cash positions to meet investor redemptions. We focus on U.S. corporate bond funds but cover their entire fixed-income portfolios. We show that fund managers tend to employ state-contingent strategies of using cash and liquid assets to accommodate investor redemptions, trading off the near-term fund performance and longer-horizon fund viability. Our results have the potential to reconcile the different conclusions reached in the literature, because the asset liquidity, uncertainty, and fund characteristics can be quite different between U.S. and emerging bond markets.

Since the seminal works of Shleifer and Vishny (1992 and 1997) and Coval and Stafford (2007), there is largely a consensus view that large institutional trades, especially flows-induced trades by open-end equity funds tend to destabilize stock prices. The evidence, however, is less clear-cut in the corporate bond market. Ellul, Jotikasthira and Lundblad (2011) exploit investment constraints of insurance companies and report evidence of fire sales of downgraded corporate bonds. Manconi, Massa, and Yasuda (2012) focus on the episode of the recent financial crisis, and Cai et al. (2016) study herd behavior among institutional investors in the corporate bond market; both studies show evidence of price impact.[4] Our study is perhaps the first to identify the time-varying impact of flows-induced mutual fund trades in the corporate bond market. This result sheds lights on the controversy regarding the price impact of mutual fund flows in the fixed-income market (see, e.g., Feroli et al., 2014; Collins and Plantier, 2014). We show that although under normal market

[4]See Kaminsky, Lyons, and Schmukler (2004) and Merrill et al. (2012) for studies on different asset classes.

conditions, the price impact of corporate bond fund trades is limited, their trading activities can lead to substantial distortions in corporate bond prices when uncertainty is high. Since the concern for financial fragility tends to be aggravated during periods with heightened uncertainty, our finding has useful policy implications.[5]

The rest of this article is organized as follows. In Section 2, we develop the main hypotheses regarding corporate bond funds' strategies to meet investor redemptions. In Section 3, we describe our sample and summary statistics. Section 4 provides the results on the liquidity management strategies of corporate bond funds. Section 5 shows the results on the fire-sale externality of corporate bond fund trading. We conclude in Section 6.

2 Strategies to Meet Investor Redemptions: Hypothesis Development

Open-end mutual funds provide their investors with both portfolio management and liquidity services. The Investment Company Act of 1940 requires that open-end funds accommodate the redemption requests from their shareholders on a daily basis. The provision of liquid claims renders effective liquidity management of open-end funds, especially those investing in illiquid asset classes such as corporate bonds, vital for the funds' smooth operation.

In this paper, we focus on the strategies of corporate bond funds to meet investor redemptions: in particular, how do they convert fund assets to cash in response to investor redemptions?[6] Our work builds on prior studies on the demand of mutual funds for liquid assets, which generally conclude that mutual funds tend to hold a certain amount of cash and liquid assets in addition to their core investment portfolio to facilitate investor redemptions.

Broadly speaking, mutual funds can employ two strategies to meet investor redemptions. They could tap into liquid asset holdings, such as cash and government bonds, pursuing what we refer to as a "horizontal cut" of their fund portfolios. Alternatively, they could liquidate a "strip" of fund holdings, selling relatively proportionally across liquid and illiquid asset classes and engaging

[5]Subsequent work has found out-of-sample support for the state-contingent nature of the trading behavior of corporate bond funds (see, e.g., Czech and Roberts-Sklar (2017) in the sterling corporate bond market).

[6]We do not consider the use of credit such as interfund lending within the same fund family and the line of credit, or in-kind payment (or even suspension of trading) as temporary means to meet investor redemptions.

in a “vertical cut” of their portfolios. In the first case, by resorting to liquid assets at hand, fund managers avoid an immediate and potentially costly liquidation of illiquid assets, thereby helping to preserve near-term performance. Essentially, this scheme of meeting investor redemptions uses liquid asset classes as a buffer to absorb the immediate influence of fund flows on a fund's core investment portfolio. Given the strong sensitivity of outflows to underperformance of corporate bond funds relative to their peers (e.g., Goldstein, Jiang and Ng, 2017), this strategy has the advantage of smoothing out the impact of investor redemptions on fund performance and future flows. This consideration leads to our first hypothesis.

Hypothesis 1 (H1 Horizontal Cut): *On average, corporate bond funds tend to reduce their liquid asset holdings in response to investor redemptions, which associates with increases in their exposures to illiquid asset classes.*

Despite the benefit of preserving near-term performance, the downside of this redemption strategy of a horizontal cut is the resulting portfolio tilt toward illiquid asset classes, which increases the vulnerability of the funds to subsequent adverse shocks. When fund managers are particularly averse to the increased vulnerability, they may prefer to use the second strategy of a vertical cut, reducing both liquid and illiquid asset holdings relatively proportionally to meet investor redemptions. By immediately selling illiquid securities with costs, they sacrifice the short-term fund performance but maintain a relatively liquid portfolio, which prevents remaining shareholders from excess exposures to illiquid assets. The benefits and costs of these two strategies vary across funds and through time, which leads to the following two hypotheses.

Across corporate bond funds, managers of those with more volatile fund flows may be particularly averse to holding a more illiquid fund portfolio after experiencing investor redemptions. Likewise, if flows of a fund tend to be highly persistent (investor redemptions tend to cluster), the manager may be less willing to increase the illiquidity of their fund portfolio following investor redemptions. Since mutual funds with higher rear-end fees may have more stable investors (Chordia, 1996), the manager may be less concerned with a temporary decline in fund performance due to costly asset liquidation leading to investor exits. These discussions lead to our second hypothesis.

Hypothesis 2 (H2 Vertical Cut: Cross-Fund Variation): *Corporate bond funds with a higher flow volatility, higher persistence in flows, and higher rear-end fees are more likely to scale down* *their assets in response to investor redemptions, preserving the liquidity of their portfolios.*

Through time, when aggregate uncertainty increases, managers of corporate bond funds may be more reluctant to reduce cash and liquid asset holdings to meet investor redemptions. The reason is that holding a more illiquid portfolio when uncertainty is expected to rise can be particularly risky. We therefore put forth our third hypothesis as follows:

Hypothesis 3 (H3 Vertical Cut: Time Variation): *When uncertainty is high, corporate bond funds tend to preserve the liquidity of their portfolios, liquidating assets more proportionally to meet investor redemptions.*

If asset managers have a target liquid asset ratio, we would expect them to replenish their liquid asset holdings after they use liquid assets to meet investor redemptions. Moreover, the speed of adjustments in the liquid asset ratio should be higher when uncertainty is high. These motivate our fourth hypothesis.

Hypothesis 4 (H4 Restoring Liquid Asset Holdings): *Following investor redemptions, corporate bond funds tend to raise liquid asset holdings, especially when uncertainty is high.*

Having discussed the strategies of corporate bond funds to meet investor redemptions at the level of asset allocations, we now consider their liquidation decision at the level of individual corporate bonds. Conditional on a fund manager's decision to liquidate corporate bonds, we hypothesize that she has incentives to minimize the liquidation costs by following a liquidity pecking order:

Hypothesis 5 (H5 Liquidity Pecking Order): *Conditional on asset liquidation, more liquid corporate bonds are more likely to be liquidated.*

A large literature is devoted to the predictability of mutual fund flows. The general message is that fund flows are predictable by past performance and past flows. Do corporate bond fund managers adopt different schemes to accommodate expected and unexpected flows? We hypothesize that the key distinction of shocks to fund flows from predictable flows is the demand for immediacy. In particular, to meet unexpected investor redemption requests, fund managers are more likely to use cash and liquid assets, instead of selling illiquid asset classes. This is a central theme of the precautionary motive for cash holdings.

Hypothesis 6 (H6 Unexpected Fund Flows): *To accommodate unexpected redemption requests, fund managers are more likely to use liquid assets, thereby increasing their exposures to illiquid asset classes.*

At the aggregate level, if corporate bond fund managers tend to rely on cash and other liquid assets to meet investor redemptions, flows-induced selling may be spread out over time, which mitigates the impact of fund selling on the corporate bond market. However, if elevated aggregate uncertainty induces corporate bond fund managers to employ a vertical cut liquidation strategy across different classes, flows-induced selling of corporate bonds may be synchronized and concentrated, which intensifies the impact of fund selling on the corporate bond market. This leads to our last hypothesis.

Hypothesis 7 (H7 Price Pressure): *Corporate bonds with larger exposures to mutual fund flows-induced selling in high-uncertainty periods tend to experience larger subsequent return reversals.*

3 Sample Construction and Summary Statistics

Our sample cover the period from 2002Q3 to 2014Q2, with data from several sources. Quarterly data on open-end corporate bond fund holdings come from the Thomson Reuters/Lipper eMAXX fixed income database. Data on mutual fund performance and characteristics are from the CRSP Survivorship-Bias-Free Mutual Fund database. Bond prices and characteristics are from Merrill Lynch and Mergent. Liquidity measures are calculated using transaction data in TRACE. We focus on dollar-denominated bonds issued by the U.S. government and companies. We further exclude bonds that are close to maturity (with less than one year to maturity) to mitigate the influence of natural bond retirement on bond liquidation results.

We select corporate bond funds based on the objective codes provided by the CRSP. Specifically, to be classified as a corporate bond fund, a mutual fund must have any of the following: a Lipper objective code in the set ('A','BBB','HY','SII','SID','IID'), a Strategic Insight objective code in the set ('CGN','CHQ','CHY','CIM','CMQ',CPR','CSM'), a Wiesenberger objective code in the set ('CBD','CHY'), 'IC' as the first two characters of the CRSP objective code, or a Lipper non-equity fund with an asset code "TX". We exclude index funds from our sample and require a matching of CRSP bond funds with the eMAXX database. This leads to a sample of 1,141 unique funds. Finally, to ensure sufficient holdings in corporate bonds, we impose a filter based on corporate bond holdings, following a bottom-up approach. Specifically, for each fixed-income mutual fund, we first calculate holdings of major asset classes by aggregating individual securities within the specific classes based on par values. To be included in our corporate bond mutual fund sample, we require a fund to have a minimum of 50% of fixed income holdings allocated to corporate bonds at least one quarter in our sample period.[7] Our final sample consists of 578 unique funds, with holdings of up to about 6,000 corporate bonds in a given quarter.

As shown in Table 1, the average cash holdings by corporate bond funds are 6.6% of total net assets (TNA), with a standard deviation of 10.5%, which indicates a substantial variation in cash holdings across funds and over time. Within fixed-income assets, corporate bond funds on average hold 9.84% assets in government bonds, 58.47% in corporate bonds, 14% in foreign holdings, and 16% in structured products including asset-backed securities (ABS), commercial mortgage-backed securities (CMBS) and residential mortgage-backed securities (RMBS).[8] The pair-wise correlations of cash holdings with other asset classes are rather mute, only 0.03 with both government securities and corporate bonds.

The mean fund flow as a percentage of total net assets, winsorized at the top and bottom 1 percentiles, is 3.80% in a given quarter, with an average time-series volatility of 8.21% and first-order autocorrelation coefficient of 0.21 based on a rolling 3-year window. Corporate bond funds tend to have a large portfolio turnover, with a turnover ratio averaging at 114%.[9]

Turning to individual corporate bonds, an average corporate bond in our sample has a mean issue size of $1.10 billion, is 3 years old, and has a coupon rate of 6.7% and a credit rating of 10.68.[10] The corporate bonds in our sample are traded with an average bid-ask spread of 1.14%, Roll illiquidity measure of 1.02%, Amihud illiquidity measure of 0.43, and inter-quarter price range

[7] We also consider other cutoff points, for instance, a filter that requires corporate bond funds to have a minimum of 20% of holdings in corporate bonds out of the total fixed-income positions at all times. The results remain qualitatively similar, as shown in Table A1.

[8] Foreign holdings consist of foreign sovereign bonds and corporate bonds, and structured product holdings include both agency-issued and non-agency issued bonds. It is unclear how their liquidity compares with that of domestic corporate bonds. Hence, for the later analysis on asset allocations, we do not consider these two asset classes.

[9] Bond funds in general have higher portfolio turnover ratios than equity funds, due, e.g., to the maturity of bonds, the call feature and the attempt of fund managers to maintain their target duration of the bond portfolio.

[10] We use numeric scores to capture the credit rating, with a higher score indicating lower credit quality. The cutoff rating score between investment-grade and high-yield corporate bonds is 11.

of 0.72%. The illiquidity measures are positively correlated, with pair-wise correlations ranging from 0.5 to near 0.8. Detailed definitions of the bond variables are reported in the Appendix.

4 Dynamic Liquidity Management

In this section, we explore liquidity management by corporate bond funds with a focus on their strategies to meet investor redemptions. We start with a detailed analysis on how bond funds change their asset allocations amid redemptions. Then we examine how bond funds liquidate individual corporate bonds to meet investor redemptions.

4.1 Changes in Asset Allocation: Horizontal versus Vertical Cuts

As discussed in Section 2, fund managers may follow two general strategies to meet investor redemption requests. The "horizontal cut" approach first taps into liquid asset classes such as cash and government bonds, which helps to preserve near-term fund performance, but may increase the illiquidity of the fund portfolio and the vulnerability of the fund to future adverse shocks. On the other hand, the "vertical cut" approach, which liquidates assets relatively proportionally across asset classes, helps to preserve the liquidity of the fund, yet entails higher upfront transaction cost and may erode near-term fund performance. The benefits and costs of the two strategies may differ considerably across funds and through time.

4.1.1 Baseline Results

We start by examining Hypothesis 1. In particular, we estimate a panel regression relating quarterly changes in fund holdings across asset classes to contemporaneous fund flows, specified as follows:

$$\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_1 Inflow_{i,t} + \beta_2 Outflow_{i,t} + \beta_3 Controls_{i,t-1} + e_{i,t}, \tag{1}$$

where $\Delta \mathit{AssetShare(\%)}_{i,t}$ is the change in the fraction of fund assets invested in a particular asset class by fund i from the end of quarter $t-1$ to the end of quarter t, quoted in per cent. We consider three major asset classes: cash, government bonds, and corporate bonds. For cash, we use the fraction of a fund's TNA held in the form of cash as available from the CRSP.[11] For government and corporate bonds, we use the ratio of government and corporate bond holdings to the fund's total fixed income holdings based on par values from the eMAXX database. We further break down corporate bond holdings into investment- and speculative-grade bonds. The advantage of using par value is to ensure that variation in the allocation between various types of bonds is not driven by changes in relative prices.

$Outflow_{i,t}$ ($Inflow_{i,t}$) equals net fund flows quoted in decimal for fund i during quarter t if it is below (above) zero, and zero otherwise. The regressions coefficients for *Inflow* and *Outflow*, β_1 and β_2, capture the effects of investor purchases and redemptions on changes in fund asset allocation. Our focus is on β_2. The strategy of a horizontal cut of portfolios to meet investor redemptions implies a positive β_2 for liquid asset holdings such as cash and government bonds, but a negative β_2 for illiquid asset holdings such as corporate bonds. In contrast, the strategy of a vertical cut implies a zero β_2 for both liquid and illiquid asset holdings.

The control variables include macro variables, such as term spreads and credit spreads, and fund characteristics including past fund performance, the natural log of TNA, log of fund family size, expenses ratio, fund turnover, front- and rear-end loads, fraction of fund assets held by retail investors, and log of fund age. The regressions also include fund- and quarter-fixed effects, and standard errors are clustered by fund.

Table 2 shows that β_2 is positive for liquid asset classes such as cash and government bonds, but negative for illiquid asset classes. In other words, amid concurrent redemptions, bond funds decrease their relative allocations to liquid assets, and increase their exposures to illiquid assets. In terms of magnitudes, a one standard deviation increase in redemptions is associated with a contemporaneous decline of $\frac{Cash}{TNA}$ by $4.226\% \times 15\% = 63bp$,[12] a decline of the weight on government securities out of fixed income holdings by $2.952\% \times 15\% = 44bp$, and an increase of relative weight on corporate

[11] Corporate bond funds may hold cash for multiple purposes, e.g., as liquidity reserves and as collateral for short-selling and security lending. There are outliers of reported cash holdings, e.g., as extreme as -80% and above 100% of TNA in the data. We impose a filter of 0 to 25% of cash holding level to better focus on cash holdings due to liquidity motives.

[12] To assess the impact on the *amount* of cash holdings due to redemptions, we estimate an alternative panel regression:

$$\frac{\Delta Cash_{i,t}}{TNA_{i,t-1}}(\%) = \beta_0 + \beta_1 Inflow_{i,t} + \beta_2 Outflow_{i,t} + \beta_3 Controls_{i,t-1} + e_{i,t},$$

The estimated coefficient suggests that \$1 outflow is associated with about 8 cents reduction in cash holdings.

bonds by $3.218\% \times 0.15 = 48bp$. These results suggest that when reacting to redemptions, fund managers, on average, tend to engage in a horizontal cut of their asset allocation along the liquidity spectrum, which supports Hypothesis 1.

4.1.2 Heterogeneity across Funds

The relative strength of the desire to preserve near-term performance and that to conserve liquidity reserves against future liquidity shocks may depend on fund characteristics. Managers of corporate bond mutual funds with more volatile flows face higher funding uncertainty. Such funding uncertainty may lead to heightened concerns about future redemptions, and hence induce a preference for fund managers to preserve the liquidity of their portfolio. In addition, managers of funds with more persistent outflows may be more concerned about the need to meet future investor redemption requests; consequently, they are less willing to engage in a horizontal cut to meet current investor redemptions. Finally, for funds with higher rear-end loads, managers may be less concerned about sacrificing near-term performance to preserve the liquidity of the portfolio. As a result, managers of those funds are more likely to pursue a vertical cut to meet investor redemptions, which forms our Hypothesis 2.

To examine this hypothesis, we conduct the following quarterly panel regressions for individual funds:

$$\begin{aligned} \Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_{1,1} Inflow_{i,t} \times LowChar_{i,t} + \beta_{1,2} Inflow_{i,t} \times HighChar_{i,t} \\ + \beta_{2,1} Outflow_{i,t} \times LowChar_{i,t} + \beta_{2,2} Outflow_{i,t} \times HighChar_{i,t} + \beta_3 Controls_{i,t-1} + e_{i,t}, \end{aligned} \tag{2}$$

where $LowChar$ and $HighChar$ capture the variation in fund characteristics: flow volatility, flow persistence, and maximum rear-end loads. More specifically, flow volatility and flow persistence are measured as the time-series standard deviation and the first-order autoregression coefficient of quarterly fund flows over 3-year historical moving windows, respectively. To capture funds with more stable investors (Chordia, 1996), we use max rear-load fees. For each fund characteristics, we construct a $LowChar$ ($HighChar$) indicator variable that takes a value of 1 if the fund's characteristic is below (above) the cross-sectional median at a given quarter, and 0 otherwise. The regressions also include fund- and quarter-fixed effects, and standard errors are clustered at the fund level.

Table 3 shows the results, which support Hypothesis 2. Panels A shows that in the regression explaining changes in a fund's proportional cash holdings, the coefficient for $Outflow$ interacted with a dummy variable of high fund flow volatility is 3.517, which is more than 40% lower than that interacted with a low fund flow volatility dummy, 6.181. This result indicates that funds with high flow volatilities are less willing to use cash to meet investor redemptions. Moreover, for high flow volatility funds, $Outflow$ has an insignificant relation to changes in government bonds and corporate bonds. These results show that these funds tend to scale down liquid and illiquid bond holdings to meet investor redemptions, engaging in the vertical cut of their portfolio. Panels B and C show results for funds with high flow persistence and rear-end loads, which provide a similar support for Hypothesis 2.

4.1.3 Aggregate Uncertainty and Fund Liquidation Strategy

The choice of bond fund liquidating strategies may also depend on aggregate uncertainty. Vayanos (2004) develops a theoretical model showing that aggregate uncertainty, proxied by market volatility, affects liquidity risk premium. An important insight from the model is that higher potential outflows associated with higher aggregate uncertainty induce fund managers to attach a higher value to liquid assets, increasing their liquidity demand. Several papers (e.g., Huang, 2013; Ben-Rephael, 2014; and Rzeznik, 2015) use equity mutual fund holdings data and find empirical support for this prediction. In the context of bond funds, we find that higher aggregate uncertainty is associated with more volatile and more persistent corporate bond fund flows. According to Vayanos (2004), the increased concern about future investor redemptions when aggregate uncertainty is elevated can elicit a stronger preference of bond fund managers for liquid assets, which in turn induces them to follow a vertical cut liquidation strategy to meet investor redemptions, our Hypothesis 3. To test this hypothesis, we add interaction terms of market volatility with contemporaneous outflows to Equation (1):

$$\begin{aligned}\Delta AssetShare(\%)_{i,t} &= \beta_0 + \beta_{1,1} Inflow_{i,t} \times LowVol_{i,t} + \beta_{1,2} Inflow_{i,t} \times HighVol_{i,t} \\ &+ \beta_{2,1} Outflow_{i,t} \times LowVol_{i,t} + \beta_{2,2} Outflow_{i,t} \times HighVol_{i,t} + \beta_3 Controls_{i,t-1} + e_{i,t},\end{aligned} \tag{3}$$

where $LowVol$ ($HighVol$) is an indicator variable that takes a value of 1 if market volatility is below (above) its historical sample median over the past 2 years, and 0 otherwise. We use CBOE 3-month implied volatility to define the state of aggregate uncertainty. All control variables in Equation (1) are also included here. The regressions also include fund-fixed effects, and standard errors are clustered at the fund level.

We report results in Table 4. For brevity, we only present estimates for interaction terms, $\beta_{2,1}$ and$\beta_{2,2}$. Panel A clearly reveals a time-varying pattern in the way fund managers adjust the asset allocations when reacting to redemptions. The interaction terms with concurrent outflows show that "horizontal cut" behaviors are observed only over periods with moderate levels of macroeconomic uncertainty: one standard deviation increase in redemptions over normal periods is associated with a decline of proportional cash holdings by $4.430\% \times 15\% = 66bp$, a decline of relative weight on government securities out of fixed income holdings by $3.741\% \times 15\% = 56bp$, and an increase of relative corporate bond holdings by $4.941\% \times 15\% = 74bp$. However, over periods of elevated aggregate uncertainty, the interaction terms of *Outflow* with *HighVol* are insignificant, consistent with managers reverting to a vertical cut approach to meet redemptions.

We further break down the 3-month expected volatility measures into upside and downside expected volatility measures, and redefine $LowVol$ ($HighVol$) indicators accordingly.[13] For instance, for the downside volatility based indicator, $LowVol$ ($HighVol$) takes a value of 1 if the expected downside volatility is above (below) its historical median, and zero otherwise. Panels B and C in Table 4 show that fund managers appear to follow a "horizontal cut" approach amid tranquil markets, and switch to a vertical cut approach amid an outlook for rising market volatility, regardless of the direction of market movements.

Overall, these results suggest that corporate bond fund managers tend to trade off in an economically meaningful way, between short-term asset liquidation costs that might jeopardize the near-term fund performance and longer-term vulnerabilities arising from reduced liquid holdings in volatile markets that might threaten future fund viability.

[13]At each time point, prices of a set of 3-month put and call options on S&P 500 from Bloomberg are used to fit a risk neutral probability distribution. Downside and upside expected volatility are calculated as various quintiles of the distributions. For example, $LowVol(HighVol)$ used here is the cumulative distribution function of a 10% or more price decline (rise). It can be interpreted that the risk neutral price of a binary option that pays $1 if the S&P500 declines (rises) by 10% or more in 3 months, and zero otherwise. Other cutoff numbers including 5% and 15% decline (rise) were considered and yield similar results.

4.1.4 Dynamic Liquidation Strategy

If shocks to investor redemptions lead funds to deviate from their desired asset allocations and liquidity levels, fund managers may need to replenish their liquid asset holdings and adjust their portfolio composition back to target levels after the shocks abate. In other words, they may dynamically manage the liquidity of their portfolio. To explore the dynamic feature in fund liquidity management, we examine Hypothesis 4. In particular, to test whether investor redemptions are associated with subsequent adjustments in a fund's liquid asset holdings (the first part of Hypothesis 4), we estimate the following quarterly panel regressions:

$$\begin{aligned}\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_1 Inflow_{i,t} + \beta_2 Outflow_{i,t} + \beta_3 Inflow_{i,t-1} \\ + \beta_4 Outflow_{i,t-1} + \gamma Controls_{i,t-1} + e_{i,t}.\end{aligned} \tag{4}$$

Control variables in Equation (1) are included. The regressions also include fund-fixed effects, and standard errors are clustered at the fund level. For brevity, we only report estimates on β_2 and β_4 in Table 5. Panel A shows that, based on the estimates on β_2, the previously documented "horizontal cut" pattern persists. The estimates on β_4 suggest that when reacting to last quarter redemptions, managers are likely to increase liquid asset holdings: a one standard deviation increase in lagged redemptions is associated with a $2.867\% \times 15\% = 43bp$ increase in proportional cash holdings, $3.542\% \times 15\% = 53bp$ increase in relative government securities holdings, and $2.531\% \times 15\% = 38bp$ decrease in relative holdings of corporate bonds. These results corroborate the conjecture that managers engage in dynamic liquidity management, replenishing their liquidity reserves following investor redemptions.

The need to replenish fund liquidity buffers may depend on market conditions. Amid elevated market volatility and heightened concerns of macroeconomic uncertainty, fund managers may have incentives to more quickly restore fund liquid reserves. To test the second part of Hypothesis 4, we add interaction terms of market volatility with contemporaneous and lagged flow variables to Equation (4) and conduct the following quarterly panel regressions:

$$
\begin{aligned}
&\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_{1,1} Inflow_{i,t} \times LowVol_t + \beta_{1,2} Inflow_{i,t} \times HighVol_t \\
&+\beta_{2,1} Outflow_{i,t} \times LowVol_t + \beta_{2,2} Outflow_{i,t} \times HighVol_t \\
&+\beta_{3,1} Inflow_{i,t-1} \times LowVol_t + \beta_{3,2} Inflow_{i,t-1} \times HighVol_t \\
&+\beta_{4,1} Outflow_{i,t-1} \times LowVol_t + \beta_{4,2} Outflow_{i,t-1} \times HighVol_t + \beta_5 Controls_{i,t-1} + e_{i,t}.
\end{aligned} \tag{5}
$$

All control variables in Equation (1) are included. The regressions also include fund-fixed effects, and standard errors are clustered at the fund level. For brevity, we only report estimates on β_2's and β_4's in Panel B of Table 5. Results on β_2's confirm our previous findings of managers following a horizontal cut amid tranquil markets but switching to a vertical cut amid volatile markets, to meet *concurrent* redemptions. Results on β_4's show that only amid volatile markets do fund managers appear to engage in dynamic portfolio adjustment prompted by past redemptions: a one standard deviation increase in past redemptions is associated with a $4.769\% \times 15\% = 72bp$ increase in proportional cash holdings, $5.386\% \times 15\% = 81bp$ increase in relative government securities holdings, and $4.460\% \times 15\% = 67bp$ decrease in relative holdings in corporate bonds over the current quarter. Overall, these results support Hypothesis 4.

4.2 Liquidating Individual Corporate Bonds: Liquidity Pecking Order

We now turn to the liquidation decisions of corporate bond fund managers at the level of individual corporate bonds. Conditional on fund managers' asset allocation decisions, we hypothesize that they implement portfolio adjustments in a cost-efficient way. In particular, they follow a "pecking order" based on the ladder of liquidity, selling more liquid corporate bonds first, in order to reduce upfront transaction costs.

We examine Hypothesis 5 in two ways. First, we estimate a logit regression at a quarterly frequency as follows:

$$
\begin{aligned}
&Logit(Sold)_{i,t} = \beta_0 + \beta_1 Outflow_{i,t} + \beta_2 BondIlliquidity_{i,t} + \beta_3 Outflow_{i,t} \times BondIlliquidity_{i,t} \\
&+\beta_4 Inflow_{i,t} + \beta_5 Inflow_{i,t} \times BondIlliquidity_{i,t} + Controls_{i,t-1} + e_{i,t}.
\end{aligned} \tag{6}
$$

The dependent variable *Sold* equals 1, if the holding of bond i is reduced over quarter t, and 0 otherwise. We use several proxies for corporate bond illiquidity: the bid-ask spread, Roll measure, Amihud measure, and the interquartile price range. $Outflow$ and $Inflow$ are defined as before. Since security liquidation decisions can be affected by many security and fund characteristics, we include a battery of control variables. Our fund-level control variables include the share of retail investors, front and rear-end loads, log of family size, fund returns, and turnover, expense ratio, and cash holdings. Our bond characteristics include current and lagged abnormal bond returns,[14] credit ratings, log of issue size, log of age, and coupon rate. The regressions also include fund-fixed and quarter-fixed effects, with standard errors clustered at the fund level.

Panel A of Table 6 shows the results. The coefficient for $Outflow$ is negative and statistically significant, which is consistent with the intuition that managers of bond funds with outflows are more likely to liquidate corporate bonds. More important, the coefficient for the interaction term of $Outflow$ and *BondIlliquidity* is positive for all four illiquidity measures, and statistically significant for three out of the four measures. This pattern of selling more liquid corporate bonds to implement portfolio adjustment is consistent with Hypothesis 5. As an alternative test specification, we repeat the above analysis using an OLS regression with the percentage of bonds sold as the dependent variable. The results, reported in Panel B of Table 6, remain qualitatively similar to those from the logit regressions.

4.3 Expected and Unexpected Redemptions

The predictability of mutual fund flows is well recognized (see, e.g., Chevalier and Ellison, 1997 and Sirri and Tufano, 1998 on equity funds; Goldstein, Jiang, and Ng, 2017 for bond funds). The broad conclusion is that past performance and past flows have substantial predictive power for mutual fund flows. Do corporate bond fund managers adopt different schemes to accommodate expected and unexpected flows? We hypothesize that the key distinction of shocks to fund flows from predictable flows is the demand for immediacy. That is, to accommodate expected investor redemptions, fund managers may have sufficient time to adjust their portfolio assets and make

[14]Bond returns tend to be highly correlated with bond features such as credit rating, coupon, and maturity. We consider abnormal bond returns, which is the residue returns after taking out the effect of aforementioned bond features. Details of bond abnormal returns are provided in the Appendix.

plans to gradually liquidate their relatively illiquid assets; to meet unexpected investor redemption requests, however, fund managers may have to rely more on cash and liquid assets, instead of adjusting their core investment portfolios. This role of liquidity to meet contingent needs is a central idea of the precautionary motive for cash holdings.

To examine our Hypothesis 6, we first decompose fund flows into expected and unexpected components. For each fund over a three-year rolling window, we conduct a time-series regression of quarterly fund flows on its lagged flows and performance. Based on the coefficients, we construct an out-of-sample forecast of the fund's expected flow in a given quarter; the unexpected flow is defined as the difference between realized and expected fund flows. Next, we re-estimate Equations (1) and (6), replacing realized flows with expected and unexpected flows in corresponding terms, while keeping all relevant control variables. The regressions also include fund- and quarter-fixed effects, and standard errors are clustered at the fund level. We summarize the results in Table 7. For brevity, we only present the results on terms involving expected and unexpected outflows.

Panel A shows a clear pattern that corporate bond fund managers tend to meet unexpected and expected investor redemptions differently. In particular, consistent with Hypothesis 6, they tend to rely more on cash and liquid assets to meet unexpected investor redemptions, but scale their assets down more proportionally across asset classes to accommodate expected redemptions. Panel B indicates that both expected and unexpected redemption requests, in general, are likely to prompt funds to sell individual corporate bonds. Interestingly, the illiquidity of individual corporate bonds has no significant relation to the likelihood of bond selling, when interacted with expected outflows; however, it has a positive and statistically significant relation to the probability of liquidation when interacted with unexpected flows. This result suggests that funds experiencing larger unexpected outflows tend to follow the liquidity pecking order more closely to liquidate individual corporate bonds, whereas funds with large expected outflows may be able to liquidate their illiquid positions as smoothly as those with small expected outflows. Overall, the results support the idea behind Hypothesis 6 that unexpected outflows have a greater demand for immediacy than expected outflows.

4.4 Robustness Tests

We conduct a number of robustness tests regarding mutual fund liquidity management practices. First, we consider alternative filters to select corporate bond funds. For instance, we use a filter that requires corporate bond funds to have a minimum of 20% of holdings in corporate bonds out of the total fixed-income positions at all times. The results, as shown in Table A1, remain qualitatively similar.

We also use expected stock market volatility index measures over different horizons ranging from 1-month to 1-year ahead. The idea is that fund managers may react differently, depending on whether the looming uncertainty is perceived to be transient or persistent. We define *LowVol* and *HighVol* indicator variables based on implied volatility of S&P500 index options with maturities ranging from 1-month to 1-year to evaluate how aggregate uncertainty at different horizons impacts how corporate bond fund managers react to investor redemptions. Panels A and B of Table A2 show that the results are qualitatively similar for short-term and long-horizon implied volatilities. Finally, we consider information from the bond market to capture the states of aggregate uncertainty. In particular, we use the implied volatility of swaptions on 10-year Treasury bonds. The results in Panels C of Table A2 provide further support to our finding that when uncertainty is elevated, corporate bond funds tend to scale down their assets, maintaining their allocations between liquid and illiquid asset classes and thereby preserving the liquidity of their portfolios.

5 Fire Sale Externality of Corporate Bond Fund Trading

We have established that corporate bond funds tend to switch their liquidation strategy from the horizontal cut during tranquil market conditions to the vertical cut amid heightened aggregate uncertainty. While the vertical cut strategy may preserve the fund liquidity and alleviate investors' concerns about excessive liquidity risk for *individual* funds, it involves selling illiquid corporate bonds at times of stress, which, at the *aggregate* level, may impose a negative externality of fire sales. To investigate whether there indeed exists such a fire sale externality, we devote this section to examining Hypothesis 7: trading pressures from bond funds at times of stress lead to temporary movements in the prices of corporate bonds, which are followed by return reversals. To conduct these tests, we use both panel regressions and portfolio sorts.

Our panel regression is specified as follows:

$$AbnormalReturn_{i,t} = \beta_0 + \beta_1 Pressure_{i,t-k} + \beta_2 Pressure_{i,t-k} \times VIX_{t-k} + e_{i,t}, \tag{7}$$

where $AbnormalReturn_{i,t}$ are computed as the raw return subtracted by the issuance size-weighted average return on a portfolio of bonds matched on credit rating, financial/nonfinancial classification, and time to maturity in that quarter as described in the Appendix. Following Coval and Stafford (2007), we measure trading pressure as:

$$Pressure_{i,t} = \frac{\sum_{f=1}^{F} \left(Buy_{f,t}^{i} | Flow_{f,t} > 90^{th} Perct - Sell_{f,t}^{i} | Flow_{f,t} < 10^{th} Perct \right)}{IssueOutstanding_{i,t-1}}.$$

It captures the difference between purchases and sales of bonds by mutual funds that experience extreme inflows and outflows, with a large negative (positive) value indicating strong selling (buying) pressure. We winsorize this variable at the top and bottom 1 percentile. For ease of interpretation, we standardize the VIX series to have a mean of zero and standard deviation of one. The regressions include fund- and quarter-fixed effect, and the standard errors are clustered at the fund level.

If flows-induced trading pressure from mutual funds affects bond pricing, we would expect a subsequent return reversal, when the price pressure ebbs away. Moreover, the reversal pattern would be stronger following high VIX periods when bond funds more actively sell corporate bonds to meet redemptions, which could exert stronger price impact on corporate bonds. Table 8 shows the results, which support these conjectures. For instance, during the period when VIX is at its mean level, a 1% selling pressure ($Pressure$=1%) on a bond in a given quarter predicts a 0.299% increase in the abnormal return on that bond in the next quarter. When VIX is one stand deviation above average, the magnitude of the return reversal more than doubles: a 1% selling pressure predicts a 0.676% increase in the bond's abnormal return during the subsequent quarter. The coefficient for the interaction between $Pressure$ and standardized VIX is large and statistically significant in the next two quarters, and tapers off subsequently.

We also perform portfolio analyses to provide additional tests on whether the price pressure from flows-driven corporate bond trading leads to subsequent return reversals. Specifically, at the beginning of each quarter, we sort all corporate bonds in our sample into quintile portfolios based on the $Pressure$ variable during the previous quarter. For each quintile portfolio, we compute the equal-weighted and par value-weighted average cumulative abnormal returns over the next 1 to 4 quarters within each quintile portfolio, and then regress the return difference between the top and bottom $Pressure$-sorted quintiles on the lagged VIX. A negative coefficient would indicate a stronger return reversal following flows-driven corporate bond trading during the high VIX period.

Table 9 presents the results with affirmative evidence. Take the equal-weighted quintile portfolios as an example. We find a negative coefficient of -0.061 for VIX, which is statistically significant at the 5 percent level. This result indicates that when VIX is one standard deviation above average ($20.27 + 1 \times 8.79 = 29.06$), the portfolio that buys bonds with large buying pressure and sells bonds with large selling pressure realizes an average abnormal quarterly return of -0.73% ($1.041 - 0.061 \times 29.06$) in the next quarter $t + 1$. This return reversal appears to continue in quarter $t + 2$, with cumulative abnormal returns reaching -1.12% ($1.583 - 0.093 \times 29.06$).[15] To summarize, both panel regressions and portfolio sorts support the notion that when corporate bond funds as a group sell corporate bonds to meet investor redemptions amid high aggregate uncertainty, the corporate bond market is under stress with excess temporary bond price movements.

6 Conclusion

In this paper, we have explored liquidity management practices by 578 open-end corporate bond mutual funds from 2002 to 2014. We find that during tranquil markets, managers of corporate bond funds tend to consume liquid assets to meet investor redemptions, temporarily increasing their exposures to illiquid asset classes. However, at times when uncertainty is elevated, fund managers tend to follow a liquidation strategy of scaling down assets relatively proportionally across liquid and illiquid asset classes, sustaining the liquidity of their portfolios. These results suggest that managers tend to trade off between short-term liquidation costs that might jeopardize the near-term fund performance and longer-term vulnerabilities arising from illiquid holdings that might threaten future fund viability.

These liquidity management practices by individual corporate bond funds appear to have unintended, negative macro-financial consequences. In particular, corporate bonds that are subject to

[15]When we extend the return horizon beyond two quarters, noise in the data renders us powerless to detect a statistically significant return reversal. This result is consistent with the finding in the panel regression that the return reversal concentrates in the two quarters after the trading pressure.

intense selling pressure from bond funds at times of elevated aggregate uncertainty exhibit strong return reversals, which is consistent with fire sales by these funds in the corporate bond market and points to potential concerns about financial stability. Overall, our study indicates that it is beneficial to consider the interplay of liquidity management, investor flows, and asset fire sales in a unified framework.

Appendix: Bond Variable Definitions

1. Quarterly abnormal return. We calculate bond quarterly raw returns using Merrill Lynch pricing data, adjusting for interests and coupon payments. In particular, raw return for bond i in quarter t is calculated as

$$r_{i,t} = \frac{(P_{i,t+1} + I_{i,t+1}) - (P_{i,t} + I_{i,t}) + D_{i,t} \times C_{i,t} \times (1 + r_{Libor,t})^{\Delta t}}{P_{i,t} + I_{i,t}} \tag{8}$$

where $P_{i,t}$ is bond i's price at the start of quarter t, $I_{i,t}$ is accrued interest , $D_{i,t}$is an indicator whether coupon payment $C_{i,t}$ occurs during quarter t. The abnormal bond return is then computed as the raw return subtracted by the size-weighted average return of the pool of bonds that share similar credit ratings, financial/nonfinancial classification, and time to maturity in that quarter.

2. Bond ratings. We use rating information obtained from three rating agencies (Moody's, Standard & Poor's, and Fitch) to compute an average rating after converting letter ratings into numerical ratings. Our general rule of conversion is to assign a larger value to a higher rating. For instance, all AAA-rated bonds across the three agencies are assigned with number 23, and all D-rated bonds are assigned with number 1.

3. Bond liquidity. We use TRACE transaction data to calculate various daily liquidity measures for each bonds. We then take the within-quarter average of daily measures to get quarterly liquidity measure.

   (a) Amihud (2002) price impact measure, defined as:

$$Liq_{i,d}^{Amd} = \frac{1}{N_{i,d}} \sum_{j=1}^{N_{i,d}} \sqrt{\frac{\left|\frac{P_{i,d}^{j} - P_{i,d}^{j-1}}{P_{i,d}^{j-1}}\right|}{Q_{i,d}^{j}}} \tag{9}$$

   where $P_{i,d}^{j}$and $Q_{i,d}^{j}$ are, respectively, the price and the size of j^{th} trade (ordered by time) of bond i on day d, and $N_{i,d}$ is the total number of trades of i on day d. The higher the Amihud measure, the more illiquid a bond is, as a larger Amihud value implies a larger price impact of trades at a given size (Kyle, 1985).

(b) Implied bid-ask spread based on Roll (1984):

$$Liq_{i,d}^{Roll} = 2\sqrt{-cov(\Delta P_{i,d}^{j}, \Delta P_{i,d}^{j-1})} \tag{10}$$

(c) Interquartile price range: an indirect measure of bid-ask spread using the interquartile range (IQR) of trade prices, defined as the difference between the 75^{th} percentile and 25^{th} percentile of prices for the day:

$$Liq_{i,d}^{IQR} = \frac{P_{i,d}^{75th} - P_{i,d}^{25th}}{P_{i,d}^{50th}} \times 100. \tag{11}$$

(d) Realized bid-ask spread, which is the difference between weighted average dealer ask prices and weighted average dealer bid prices. The weights are par volume of trades.

References

Ben-Rephael, A. 2014. Flight-to-Liquidity, Market Uncertainty, and the Actions of Mutual Fund Investors. Indiana University Working Paper.

Cai, F., Han, S., Li, D., and Li, Y. 2016. Institutional Herding and Its Price Impact: Evidence from the Corporate Bond Market. Working Paper.

Chen, Q., Goldstein, I., and Jiang, W. 2010. Payoff Complementarities and Financial Fragility: Evidence from Mutual Fund Outflows. *Journal of Financial Economics* 97, 239-262.

Chernenko, S. and Sunderam, A. 2015. Liquidity Transformation in Asset Management: Evidence from the Cash Holdings of Mutual Funds. Working Paper.

Chordia, T., 1996. The Structure of Mutual Fund Charges. *Journal of financial Economics* 41, 3-39.

Collins, S., and Plantier, C., 2014. Are Bond Mutual Fund Flows Destabilizing? Examining the Evidence from the 'Taper Tantrum'. Working Paper.

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

Czech, R., and Roberts-Sklar, M., 2017, Investor behaviour and reaching for yield: evidence from the sterling corporate bond market. Bank of England Staff Working Paper No. 685.

Diamond, D., and Dybvig,P. 1983. Bank Runs, Deposit Insurance, and Liquidity, *Journal of Political Economy* 91, 401-419.

Dick-Nielsen, J., Feldhutter, P., and Lando, D. 2012. Corporate Bond Liquidity Before and After the Onset of the Subprime Crisis, *Journal of Financial Economics* 103, 471-492.

Ellul, A., Jotikasthira,C., and Lundblad, C. 2011. Regulatory Pressure and Fire Sales in the Corporate Bond Market, *Journal of Financial Economics* 101, 596-620.

Feroli, M., Kashyap, A. K., Schoenholtz, K. L., and Shin, H. S. 2014. Market tantrums and monetary policy. Chicago Booth Research Paper No. 14-09.

Fulkerson, J. A., and Riley, T. B. 2015. Mutual Fund Liquidity Costs, Working paper, Loyola University.

Goldstein, I., Jiang, H., and Ng, D. 2017. Investor Flows and Fragility in Corporate Bond Funds. *Journal of Financial Economics*, Forthcoming.

Gorton, G. and Metrick, A. 2010. Regulating the Shadow Banking System, *Brookings Papers on Economic Activity*, 261-297.

Gorton, Gary, and Penacchi, G. 1990. Financial Intermediaries and Liquidity Creation, *Journal of Finance* 45, 49-72.

Greenwood, R. and Thesmar, D. 20111 Stock Price Fragility, *Journal of Financial Economics* 102, 471-490.

Hanouna, P., Novak, J., Riley, T., and Stahel, C. 2015. Liquidity and Flows of U.S. Mutual Funds, Division of Economic and Risk Analysis White Paper, U.S. Securities and Exchange Commission.

Huang, J. 2015. Dynamic Liquidity Preferences of Mutual Funds. University of Illinois Working Paper.

IMF 2015. Global Financial Stability Report. Chapter 3. `http://www.imf.org/external/pubs/ft/gfsr/2015/01/pdf/c3.pdf`.

Kaminsky, G., Lyons, R., and Schmukler, S. 2004. Managers, investors, and crises: mutual fund strategies in emerging markets, *Journal of International Economics* 64, 113-134.

Krishnamurthy, A. and Vissing-Jorgensen, A. 2015. The Impact of Treasury Supply on Financial Sector Lending and Stability, *Journal of Financial Economics* 118, 571-600.

Liu, X. and Mello, A. 2011. The Fragile Capital Structure of Hedge Funds and the Limits to Arbitrage, *Journal of Financial Economics* 102, 491-506.

Manconi, A., Massa, M., and Yasuda, A. 2012. The Role of Institutional Investors in Propagating the Financial Crisis of 2007-2008. *Journal of Financial Economics* 104, 491-518.

Massa, M., Yasuda, A., Zhang, L. 2013. Supply Uncertainty of the Bond Investor Base and the Leverage of the Firm. *Journal of Financial Economics* 110, 185-214.

Merrill, C., Nadauld, T., Sherlund, S. and Stulz, R. 2012. Did Capital Requirements and Fair Value Accounting Spark Fire Sales in Distressed Mortgage Backed Securities? NBER Working Paper No. 18270.

Morris, S., Shim, I., and Shin, H. 2017. Redemption Risk and Cash Hoarding by Asset Managers. *Journal of Monetary Economics* 89, 71-87.

Nagel, S. 2012, Evaporating Liquidity. *Review of Financial Studies* 25, 2005-2039.

Oet, M. V., Dooley,J. M., & Ong, S. J. (2015). The Financial Stress Index: Identification of Systemic Risk Conditions. *Risks* 3(3), 420-444.

Rzeznik, A. 2015. Mutual Fund Flight-to-liquidity. Working Paper.

Shek, J., Shim, I., Shin, H. 2015. Investor Redemptions and Fund Managers Sales of Emerging Market Bonds: How are They Related? BIS Working Paper.

Shleifer, A. and Vishny, R. 1992. Liquidation Values and Debt Capacity: A Market Equilibrium Approach, *Journal of Finance* 47, 1343-1366.

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

Simutin, M. 2014, Cash Holdings and Mutual Fund Performance, *Review of Finance* 18, 1425-1464.

Stein, J., 2014. Comments on "Market Tantrums and Monetary Policy," a paper by Michael Feroli, Anil Kashyap, Kermit Schoenholtz, and Hyun Song Shin. Remarks at the U.S. Monetary Policy Forum.

Yan, X. 2006. The Detriments and Implications of Mutual Fund Cash Holdings, *Financial Management* 35, 67-91.

Zeng, Y. 2015. A Dynamic Theory of Mutual Fund Runs and Liquidity Management. Harvard University Working Paper.

Table 1: Summary Statistics

This table shows the summary statistics for characteristics of corporate bond funds and corporate bonds in our sample from 2002Q1 to 2014Q2. Fund characteristics include Cash Holdings (%) as the proportion of fund assets held in cash; relative weight (%) out of total fixed-income securities in U.S. Treasury bonds, domestic corporate bonds including investment grade and high yield bonds, foreign holdings, and structured products including agency and non-agency issues; Quarterly Fund Flow (%), Quarterly Flow Volatility (%) and first-order autoregressive coefficient (AR1) based on last 3 years flows; TNA (million $); Family Size (million $); Quarterly Fund Return (%); Age in years; Max Front-end and Rear-end Load (%); Expense Ratio (%); Turnover; and Retail Investor Share (fraction of funds owned by retail investors). Corporate bond characteristics include Roll illiquidity (%), bid-ask spread (%), Amihud illiquidity, inter-quartile price range (%), Abnormal Quarterly Return(%), Credit Rating, Issue Size (million $), Age (years) and Coupon Rate (%).

Fund Level:	Mean	Stdev	p5	p25	p50	p75	p95	N
Cash Holdings (%)	6.60	10.48	0.00	1.67	3.63	7.00	24.62	16490
% of Fixed-income in Government Bonds	9.84	16.38	0.00	0.00	2.00	14.45	42.86	17540
% of Fixed-income in Corporate Bonds	58.47	27.47	10.62	36.95	59.46	84.56	93.97	17540
% in Investment Grade	20.79	22.17	0.00	1.08	13.83	35.59	64.53	17529
% in High Yield	37.72	36.38	0.00	4.70	19.77	81.41	92.15	17529
% of Fixed-income in Foreign Holdings	14.34	14.70	0.00	5.49	10.45	17.71	42.14	17540
% of Fixed-income in Structured Products	16.11	21.45	0.00	0.14	4.34	28.41	60.04	17540
% in Agency Issues	8.41	13.54	0.00	0.00	1.14	12.45	36.74	17540
% in NonAgency Issues	7.70	12.55	0.00	0.00	1.50	11.30	33.21	17540
Quarterly Fund Flow(%)	3.80	15.01	-11.27	-3.38	0.53	6.52	29.74	19052
Quarterly Fund Flow Volatility(%)	8.21	6.76	1.73	3.76	6.09	10.52	22.12	11066
AR1 of Quarterly Fund Flow	0.21	0.34	-0.35	-0.05	0.21	0.47	0.75	13941
TNA(M$)	1245	3214	13	84	292	942	5888	19937
Family Size (M$)	12446	46783	48	497	2308	7704	34474	19937
Quarterly Return (%)	1.37	3.75	-3.27	0.00	1.20	2.78	6.37	19937
Age (Years)	13.39	11.54	1.00	5.27	11.40	18.02	33.11	19936
Max Rear-end Load (%)	0.50	0.76	0.00	0.00	0.01	1.00	2.00	19937
Max Front-end Load (%)	0.93	1.33	0.00	0.00	0.06	1.76	3.69	19937
Expense Ratio (%)	0.90	0.35	0.36	0.66	0.86	1.11	1.52	18785
Turnover	1.14	1.29	0.20	0.43	0.71	1.27	3.79	18642
Retail Investor Share	0.57	0.42	0.00	0.06	0.72	1.00	1.00	19936
Corporate Bond Level:								
Roll Illiquidity (%)	1.02	0.83	0.16	0.45	0.81	1.35	2.48	987564
Bid-ask Spread (%)	1.14	0.94	0.12	0.45	0.91	1.61	2.90	977605
Amihud Illiquidiity	0.43	0.28	0.06	0.22	0.40	0.57	0.90	1076295
Inter-quarter Price Range (%)	0.72	0.62	0.06	0.29	0.56	0.98	1.84	1077158
Abnormal Quarterly Return (%)	-0.13	5.04	-6.65	-1.33	-0.08	1.23	6.10	1077158
Credit Rating	10.68	3.98	4.33	7.67	10.67	14.00	17.00	1077158
Issue Size (M$)	1109	1325	250	500	750	1400	3000	1077158
Age (Years)	3.10	2.74	1.00	1.00	2.00	4.00	8.00	1077158
Coupon Rate (%)	6.74	1.98	3.25	5.60	6.75	8.00	10.00	1077158

Table 2: Changes in Fund Asset Allocation in Response to Redemptions

This table reports the results of panel regressions of changes in holdings of various asset classes, in percent, on $Outflow$ ($Inflow$), in decimal, at the quarterly frequency, specified as follows:

$$\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_1 Inflow_{i,t} + \beta_2 Outflow_{i,t} + \gamma Controls_{i,t-1} + e_{i,t}.$$

We winsorize fund flows at the top and bottom 1% level, and standardize the natural log of TNA and Family size of the funds relative to their means. Other control variables include Expense Ratio, Turnover, Front Load, Rear Load, Share of Retail, Log of Fund Age, Quarterly Fund Return, Credit Spreads as the difference in yields between the 10-year Treasury and investment-grade corporate bonds, Term Spreads as the difference in yields between the 10-year and 1-year Treasury notes. We include fund- and quarter-fixed effects in the regressions, and cluster standard errors at the fund level, as reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

	ΔCash	ΔGovernment Bonds	ΔCorporate Bonds	ΔInvestment Grade	ΔHigh Yield
Inflow	0.798*	1.020***	0.447	0.546*	-0.299
	(0.47)	(0.36)	(0.51)	(0.32)	(0.31)
Outflow	4.226***	2.952***	-3.218***	-0.852	-1.769**
	(1.04)	(1.07)	(1.19)	(0.90)	(0.74)
$Log(TNA)_{t-1}$	-0.205	-0.166	0.231*	0.129	0.074
	(0.15)	(0.12)	(0.13)	(0.11)	(0.08)
$Log(FamilySize)_{t-1}$	-0.019	-0.265*	-0.453**	-0.217	-0.154
	(0.16)	(0.15)	(0.19)	(0.15)	(0.12)
$ExpenseRatio_{t-1}$	41.564	-46.985	-18.019	-11.074	-9.033
	(37.48)	(37.42)	(46.46)	(29.70)	(29.74)
$TurnoverRatio_{t-1}$	0.036	-0.212***	0.117**	0.078*	0.022
	(0.07)	(0.06)	(0.06)	(0.04)	(0.04)
$FrontLoad_{t-1}$	-0.049	-0.162*	0.047	0.038	0.002
	(0.06)	(0.08)	(0.10)	(0.06)	(0.06)
$RearLoad_{t-1}$	-0.086	-0.018	0.117	0.033	0.079
	(0.09)	(0.07)	(0.08)	(0.06)	(0.05)
$ShareofRetail_{t-1}$	-0.23	0.319	-0.052	0.026	-0.071
	(0.27)	(0.28)	(0.33)	(0.24)	(0.19)
$Log(Age)_{t-1}$	0.346	0.414**	-0.506**	-0.216	-0.252*
	(0.21)	(0.16)	(0.24)	(0.17)	(0.15)
$QuarterlyFundReturn_{t-1}$	-0.017	-0.032**	0.043**	0.034**	0.004
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
$TermSpread_{t-1}$	-4.620**	0.172	0.509*	0.162	0.423**
	(2.18)	(0.22)	(0.27)	(0.18)	(0.18)
$CreditSpread_{t-1}$	1.820***	-0.186	-0.033	0.284*	-0.384***
	(0.70)	0.18)	(0.23)	(0.16)	(0.13)
Constant	7.259	-0.324	0.371	-0.905*	1.400***
	(4.43)	(0.63)	(0.77)	(0.52)	(0.48)
Adjusted R-squared	0.064	0.024	0.04	0.054	0.048
Fund-Quarter Observations	13,868	15,627	15,627	15,616	15,616

Table 3: Changes in Fund Asset Allocation in Response to Redemptions: Effects of Fund Characteristics

This table reports the results of quarterly panel regressions of changes in asset allocations across various asset classes, in percent, on $Outflow$ ($Inflow$), in decimal, and their interaction terms with fund characteristics as follows:

$$\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_{1,1} Inflow_{i,t} \times LowChar_{i,t} + \beta_{1,2} Inflow_{i,t} \times HighChar_{i,t}$$
$$+\beta_{2,1} Outflow_{i,t} \times LowChar_{i,t} + \beta_{2,2} Outflow_{i,t} \times HighChar_{i,t} + \gamma Controls_{i,t-1} + e_{i,t}.$$

The $LowChar$ ($HighChar$) indicator variable takes a value of 1 if the fund's particular characteristic is below (above) the cross-sectional median at a given quarter, and 0 otherwise. Panel A reports results when the fund characteristic is flow volatilities, Panel B the flow persistence, and Panel C maximum rear end fee. We winsorize fund flows at the top and bottom 1% level, and standardize the natural log of TNA and Family size of the funds relative to their means. Other control variables include Expense Ratio, Turnover, Front Load, Rear Load, Share of Retail, Log of Fund Age, Quarterly Fund Return, Credit Spreads (difference in yields between the 10-year Treasury and investment-grade corporate bonds), Term Spreads(difference in yields between the 10-year and 1-year Treasury notes). We include fund- and quarter-fixed effects in the regressions, and cluster standard errors at the fund level, as reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

Interaction of Fund Characteristics with Outflow	ΔCash	ΔGovernment Bonds	ΔCorporate Bonds	ΔInvestment Grade	ΔHigh Yield
Panel A: Flow Volatilities					
$LowChar \times Outflow$	6.181***	5.847***	-7.496***	-4.333***	-2.781*
	(1.63)	(1.67)	(2.09)	(1.55)	(1.42)
$HighChar \times Outflow$	3.517***	1.687	-1.331	0.747	-1.445*
	(1.28)	(1.30)	(1.42)	(1.08)	(0.82)
Panel B: Flow Persistence					
$LowChar \times Outflow$	5.088***	3.966***	-3.533**	-0.568	-2.255**
	(1.33)	(1.47)	(1.60)	(1.23)	(0.96)
$HighChar \times Outflow$	3.077*	1.802	-2.601	-1.033	-1.154
	(1.58)	(1.52)	(1.74)	(1.31)	(1.04)
Panel C: Max Rear-end Loads					
$LowChar \times Outflow$	7.166***	5.715***	-2.975*	-0.108	-2.031**
	(1.50)	(1.53)	(1.73)	(1.33)	(0.93)
$HighChar \times Outflow$	0.85	-0.341	-3.519**	-1.74	-1.462
	(1.48)	(1.47)	(1.56)	(1.21)	(1.11)

Table 4: Changes in Fund Asset Allocation in Response to Redemptions: Effects of Aggregate Uncertainty

This table reports the results of quarterly panel regressions of changes in asset allocations across various asset classes, in percent, on $Outflow$ ($Inflow$), in decimal, and their interaction terms with aggregate uncertainty as follows:

$$\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_{1,1} Inflow_{i,t} \times LowVol_t + \beta_{1,2} Inflow_{i,t} \times HighVol_t$$
$$+\beta_{2,1} Outflow_{i,t} \times LowVol_t + \beta_{2,2} Outflow_{i,t} \times HighVol_t + \gamma Controls_{i,t-1} + e_{i,t}.$$

The $LowVol$ ($HighVol$) indicator variable takes a value of 1 if market volatility is below (above) historical sample median, and 0 otherwise. Panel A reports results when $LowVol$ ($HighVol$) is based on the 3-month CBOE volatility, Panel B on 3-month expected downside volatility, and Panel C on 3-month expected upside volatility. We winsorize fund flows at the top and bottom 1% level, and standardize the natural log of TNA and Family size of the funds relative to their means. Other control variables include Expense Ratio, Turnover, Front Load, Rear Load, Share of Retail, Log of Fund Age, Quarterly Fund Return, Credit Spreads as the difference in yields between the 10-year Treasury and investment-grade corporate bonds, Term Spreads as the difference in yields between the 10-year and 1-year Treasury notes. We include fund-fixed effects in the regressions, and cluster standard errors at the fund level, as reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

Interaction of Volatility with Outflow	ΔCash	ΔGovernment Bonds	ΔCorporate Bonds	ΔInvestment Grade	ΔHigh Yield
Panel A: 3-Month Volatility					
$LowVol \times Outflow$	4.430***	3.741***	-4.941***	-1.947***	-2.570*
	(1.16)	(1.24)	(1.41)	(1.03)	(0.81)
$HighVol \times Outflow$	1.457	2.402	-2.503	0.954	-0.632
	(1.91)	(1.70)	(2.01)	(1.67)	(1.21)
Panel B: 3-Month Downside Volatility					
$LowVol \times Outflow$	4.168***	2.997***	-5.676**	-2.414*	-2.664**
	(1.22)	(1.48)	(1.60)	(1.25)	(0.90)
$HighVol \times Outflow$	2.261	3.371**	-2.614	-.894	-1.038
	(1.63)	(1.42)	(1.65)	(1.39)	(1.01)
Panel C: 3-Month Upside Volatility					
$LowVol \times Outflow$	4.322***	4.785***	-5.303***	-2.070**	-2.798*
	(1.14)	(1.23)	(1.41)	(1.01)	(0.82)
$HighVol \times Outflow$	1.611	0.874	-1.864	-0.688	-0.24
	(1.98)	(1.75)	(2.10)	(1.71)	(1.24)

Table 5: Changes in Fund Asset Allocation in Response to Redemptions: Dynamic Relations

This table reports the results of quarterly panel regressions of changes in asset allocations across various asset classes, in percent, on $Outflow$ ($Inflow$), in decimal, and their interaction terms with aggregate uncertainty. Panel A presents results for the regressions specified as follows:

$$\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_1 Inflow_{i,t} + \beta_2 Outflow_{i,t} + \beta_3 Inflow_{i,t-1} + \beta_4 Outflow_{i,t-1} + \gamma Controls_{i,t-1} + e_{i,t}.$$

Panel B for the regressions as follows:

$$\begin{aligned}
&\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_{1,1} Inflow_{i,t} \times LowVol_t + \beta_{1,2} Inflow_{i,t} \times HighVol_t \\
&+\beta_{2,1} Outflow_{i,t} \times LowVol_t + \beta_{2,2} Outflow_{i,t} \times HighVol_t \\
&+\beta_{3,1} Inflow_{i,t-1} \times LowVol_t + \beta_{3,2} Inflow_{i,t-1} \times HighVol_t \\
&+\beta_{4,1} Outflow_{i,t-1} \times LowVol_t + \beta_{4,2} Outflow_{i,t-1} \times HighVol_t + \gamma Controls_{i,t-1} + e_{i,t}.
\end{aligned}$$

The $LowVol$ ($HighVol$) indicator variable takes a value of 1 if 3-month CBOE volatility is below (above) historical sample median, and 0 otherwise. Panel A reports results when $LowVol$ ($HighVol$) is based on the 3-month CBOE volatility, Panel B on 3-month expected downside volatility, and Panel C on 3-month expected upside volatility. We winsorize fund flows at the top and bottom 1% level, and standardize the natural log of TNA and Family size of the funds relative to their means. Other control variables include Expense Ratio, Turnover, Front Load, Rear Load, Share of Retail, Log of Fund Age, Quarterly Fund Return, Credit Spreads (difference in yields between the 10-year Treasury and investment-grade corporate bonds), Term Spreads (difference in yields between the 10-year and 1-year Treasury notes). We include fund-fixed effects in the regressions, and cluster standard errors at the fund level, as reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

	ΔCash	ΔGovernment Bonds	ΔCorporate Bonds	ΔInvestment Grade	ΔHigh Yield
Panel A: Baseline					
$Outflow$	5.007***	3.993***	-3.988***	-1.176***	-2.089*
	(1.16)	(1.09)	(1.29)	(1.00)	(0.77)
$Outflow_{t-1}$	-2.867***	-3.542***	2.531**	0.813	0.904
	(1.03)	(1.10)	(1.21)	(0.94)	(0.69)
Panel B: 3-Month Volatility					
$LowVol \times Outflow$	4.830***	3.964***	-5.160***	-2.212**	-2.605***
	(1.32)	(1.28)	(1.51)	(1.12)	(0.82)
$HighVol \times Outflow$	2.501	4.124**	-3.892*	-1.277	-1.33
	(1.97)	(1.78)	(2.17)	(1.86)	(1.29)
$LowVol \times Outflow_{t-1}$	-1.864*	-2.033	1.945	0.767	0.8
	(1.13)	(1.32)	(1.48)	(1.07)	(0.87)
$HighVol \times Outflow_{t-1}$	-4.769**	-5.386***	4.460**	0.948	2.082*
	(1.99)	(1.82)	(2.16)	(1.74)	(1.24)

Table 6: Security Liquidation: Liquidity Pecking Order

Panel A reports the results of quarterly logit regressions of selling a corporate bond on $Outflow$ ($Inflow$), in decimal, bond illiquidity, and their interaction terms. If a corporate bond holding is reduced over quarter t, the LHS is entered as 1, and 0 otherwise. Panel B reports the quarterly OLS pooled regressions of the percentage of bonds sold on $Outflow$ ($Inflow$), in decimal, bond illiquidity, and their interaction terms. We winsorize fund flows at the top and bottom 1 percentiles. Corporate bond illiquidity is measured by Bid-Ask spread, Roll's illiquidity, Amihud illiquidity, and inter-quartile price range (IQR). Bond-level control variables include current and lagged abnormal bond returns, and lagged bond characteristics including credit rating, issue size and bond age standardized to the means, and coupon rate (%). Fund-level control variables include the natural log of standardized Family Size, Expense Ratio, Turnover, Front Load, Rear Load, Share of Retail, Quarterly Fund Return, and Cash Holdings. We include fund- and quarter-fixed effects in the regressions, and cluster standard errors at the fund level, as reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

Panel A:	Sale Indicator (Logit)			
	Bid-Ask	Roll	Amihud	IQR
$Outflow$	-3.876***	-3.922***	-3.927***	-3.939***
	(0.33)	(0.34)	(0.34)	(0.34)
$Inflow$	-0.756***	-0.762***	-0.753***	-0.753***
	(0.16)	(0.16)	(0.16)	(0.16)
Illiquidity	-0.017*	0.025**	-0.019**	0.014
	(0.01)	(0.01)	(0.01)	(0.01)
$Outflow$ × *Illiquidity*	0.234*	0.282**	0.046	0.252**
	(0.13)	(0.12)	(0.12)	(0.12)
$Inflow$ × *Illiquidity*	-0.015	0.025	-0.013	0.032
	(0.07)	(0.07)	(0.05)	(0.07)
Bond-Fund-Quarter Observations	761,586	769,331	840,245	840,963
Panel B:	Percentage Sold (OLS)			
	Bid-Ask	Roll's	Amihud	IQR
$Outflow$	-0.272***	-0.273***	-0.271***	-0.270***
	(0.04)	(0.04)	(0.04)	(0.04)
$Inflow$	-0.015	-0.015	-0.014	-0.015
	(0.01)	(0.01)	(0.01)	(0.01)
Illiquidity	-0.002**	0.002*	-0.002**	0.001
	(0.00)	(0.00)	(0.00)	(0.00)
$Outflow$ × *Illiquidity*	0.032**	0.015	0.031**	0.02
	(0.02)	(0.02)	(0.01)	(0.01)
$Inflow$ × *Illiquidity*	-0.006	0.005	-0.004	-0.004
	(0.01)	(0.01)	(0.00)	(0.00)
Adjusted R-Squared	0.069	0.07	0.068	0.068
Bond-Fund-Quarter Observations	704,699	712,507	778,431	779,114

Table 7: Responses to Expected and Unexpected Redemptions

Panel A reports the results of quarterly panel regressions of changes in various asset class holdings, in percent, on expected and unexpected $Outflow$ ($Inflow$), in decimal. The control variables are similar to Table 2. Panel B reports the quarterly logistic regressions of bond selling and OLS resgressions of percentage of bonds sold as in Table 6. All control variables are included. For both panels, we include fund- and quarter-fixed effects, and report in parentheses the standard errors clustered at the fund level. *** 1% significance; ** 5% significance; * 10% significance.

Panel A: Changes in Asset Allocations in Response to Redemptions

	ΔCash	ΔGovernment Bonds	ΔCorporate Bonds	ΔInvestment Grade	ΔHigh Yield
$Outflow^{exp}$	1.695	0.864	1.014	-0.104	0.852
	(1.54)	(1.58)	(1.59)	(1.20)	(0.89)
$Outflow^{un}$	2.470***	2.817***	-2.580***	-1.519*	-0.554
	(0.92)	(0.81)	(0.99)	(0.78)	(0.63)

Panel B: Security Liquidation

	Sale Indicator (Logit)				Percentage Sold (OLS)			
	Bid-Ask	Roll	Amihud	IQR	Bid-Ask	Roll	Amihud	IQR
$Outflow^{exp}$	-1.393**	-1.329**	-1.364**	-1.365**	0.007	0.012	0.011	0.013
	(0.64)	(0.65)	(0.65)	(0.65)	(0.07)	(0.07)	(0.07)	(0.07)
$Outflow^{un}$	-3.120***	-3.138***	-3.161***	-3.167***	-0.181***	-0.177***	-0.180***	-0.179***
	(0.34)	(0.34)	(0.34)	(0.34)	(0.04)	(0.04)	(0.04)	(0.04)
$Outflow^{exp} \times Illiquidity$	-0.113	-0.189	0.07	-0.162	0.003	0.001	0.039*	-0.004
	(0.21)	(0.21)	(0.21)	(0.18)	(0.02)	(0.02)	(0.02)	(0.02)
$Outflow^{un} \times Illiquidity$	0.289**	0.397***	0.024	0.294**	0.027**	0.02	0.016	0.013
	(0.13)	(0.13)	(0.11)	(0.12)	(0.01)	(0.01)	(0.01)	(0.01)

Table 8: Price of Impact of Trading Pressure: Panel Regression

This table reports the quarterly panel regression results of quarterly abnormal bond returns on measures of lagged mutual fund trading pressures as well as the interaction terms of trading pressures with VIX, specified as follows:

$$AbnormalReturn_{i,t} = \beta_0 + \beta_1 \text{Pressure}_{i,t-k} + \beta_2 \text{Pressure}_{i,t-k} \times VIX_{t-k} + e_{i,t}.$$

The abnormal bond return is computed as the raw bond return subtracted by the size-weighted average return of the pool of bonds that share similar credit ratings, financial/nonfinancial classification, and time to maturity in that quarter. Mutual fund trading induced pressure, $Pressure$, is defined based on Coval and Stafford (2007) as

$$\frac{\sum_{f=1}^{F}\left(Buy^{i}_{f,t}|Flow_{f,t} > 90^{th}Percentile - Sell^{i}_{f,t}|Flow_{f,t} < 10^{th}Percentile\right)}{IssueOutstanding_{i,t-1}}.$$

The pressure variable is winsorized at the top and bottom 1 percentiles. For ease of interpretation, we standardize the VIX to have a mean of zero and standard deviation of one. Fund- and quarter-fixed effects are controlled for in the regression. The standard errors reported in parentheses are clustered at the fund level. *** 1% significance; ** 5% significance; * 10% significance.

	(1)	(2)	(3)	(4)
$Pressure_{t-1}$	-0.299***			
	(0.06)			
$(Pressure \times VIX)_{t-1}$	-0.377***			
	(0.12)			
$Pressure_{t-2}$		-0.0977*		
		(0.06)		
$(Pressure \times VIX)_{t-2}$		-0.387***		
		(0.10)		
$Pressure_{t-3}$			-0.0215	
			(0.08)	
$(Pressure \times VIX)_{t-3}$			-0.126	
			(0.14)	
$Pressure_{t-4}$				-0.242***
				(0.08)
$(Pressure \times VIX)_{t-4}$				-0.0885*
				(0.05)
Constant	-0.0140***	0.00177***	-0.00383*	0.00233***
	(0.00)	(0.00)	(0.00)	(0.00)
Adjusted R-squared (%)	0.398	0.365	0.343	0.362
Bond-Quarter Observations	190,069	172,887	157,639	143,876

Table 9: Price Impact of Trading Pressure: Portfolio Sorting

This table reports the results from quarterly regressions of the difference in cumulative abnormal returns between high and low trading pressure quintiles on the lagged VIX variable:

$$CumAbnormalReturn_{t,t+k}^{Hi-Low} = \beta_0 + \beta_1 VIX_t + e_t, k = 1, 2, 3, 4.$$

Each quarter, we construct quintile portfolios by sorting corporate bonds based on the level of $Pressure$. We compute equal-weighted (par value-weighted) cumulative abnormal returns as the simple (par-weighted weighted) average of the cumulative abnormal bond returns over the next 1 to 4 quarters within each quintile. Abnormal bond return, in percent, is the raw bond return subtracted by the size-weighted average return of the portfolio of bonds matched on credit rating, financial/nonfinancial classification, and time to maturity in that quarter. The $CumAbnormalReturn^{Hi-Low}$ is the difference in cumulative abnormal returns between the high- and low-Pressure quintiles. The Newey-West standard errors are reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

		Qtr_{t+1}	$Qtr_{t+1\to t+2}$	$Qtr_{t+1\to t+3}$	$Qtr_{t+1\to t+4}$
EW	Constant	1.041*	1.583*	0.414	0.485
		(0.538)	(0.847)	(0.310)	(0.492)
	VIX_t	-0.061**	-0.093*	-0.041	-0.008
		(0.031)	(0.050)	(0.026)	(0.021)
PVW	Constant	0.667	1.203*	0.374	0.010
		(0.416)	(0.661)	(0.393)	(0.651)
	VIX_t	-0.038	-0.069*	-0.034	-0.025
		(0.024)	(0.039)	(0.026)	(0.025)

Appendices

Internet Appendix

Table A1: Changes in Fund Asset Allocation in Response to Redemptions: An Alternative Sample

This table reports the results of panel regressions of changes in holdings of various asset classes, in percent, on $Outflow$ ($Inflow$), in decimal, at the quarterly frequency, specified as follows:

$$\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_1 Inflow_{i,t} + \beta_2 Outflow_{i,t} + \gamma Controls_{i,t-1} + e_{i,t}.$$

The sample includes corporate bond funds holding at least 20% of their fixed-income assets in corporate bonds at all times. We winsorize fund flows at the top and bottom 1% level, and standardize the natural log of TNA and Family size of the funds relative to their means. Other control variables include Expense Ratio, Turnover, Front Load, Rear Load, Share of Retail, Log of Fund Age, Quarterly Fund Return, Credit Spreads as the difference in yields between the 10-year Treasury and investment-grade corporate bonds, Term Spreads as the difference in yields between the 10-year and 1-year Treasury notes. We include fund- and quarter-fixed effects in the regressions, and cluster standard errors at the fund level, as reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

	ΔCash	ΔGovernment Bonds	ΔCorporate Bonds	ΔInvestment Grade	ΔHigh Yield
Inflow	0.522	0.652**	-0.064	0.461	-0.636*
	(0.49)	(0.32)	(0.49)	(0.33)	(0.35)
Outflow	4.781***	1.955**	-3.102***	-1.040	-1.627*
	(1.14)	(0.97)	(1.17)	(0.94)	(0.95)
$Log(TNA)_{t-1}$	-0.322**	-0.173	0.264**	0.098	0.124
	(0.15)	(0.12)	(0.13)	(0.11)	(0.10)
$Log(FamilySize)_{t-1}$	0.043	-0.239*	-0.167	-0.089	-0.010
	(0.16)	(0.14)	(0.18)	(0.15)	(0.13)
$ExpenseRatio_{t-1}$	113.851***	-15.925	-10.582	-7.043	-8.356
	(40.26)	(29.46)	(39.68)	(27.45)	(29.84)
$TurnoverRatio_{t-1}$	-0.023	-0.088	0.117*	0.107*	0.008
	(0.07)	(0.05)	(0.06)	(0.06)	(0.05)
$FrontLoad_{t-1}$	-0.001	-0.121	0.111	0.089	0.024
	(0.08)	(0.10)	(0.12)	(0.07)	(0.08)
$RearLoad_{t-1}$	-0.142*	-0.080	0.183***	0.041	0.123**
	(0.08)	(0.06)	(0.07)	(0.06)	(0.06)
$ShareofRetail_{t-1}$	-0.336	0.257	-0.228	-0.073	-0.076
	(0.30)	(0.25)	(0.34)	(0.25)	(0.21)
$Log(Age)_{t-1}$	0.386*	0.181	-0.356*	-0.246*	-0.067
	(0.22)	(0.15)	(0.20)	(0.13)	(0.16)
$QuarterlyFundReturn_{t-1}$	-0.022	-0.016	0.026	0.011	0.016
	(0.02)	(0.01)	(0.02)	(0.01)	(0.01)
$TermSpread_{t-1}$	-4.230*	-1.610	2.071	5.057*	-1.563
	(2.16)	(2.97)	(4.16)	(2.58)	(3.15)
$CreditSpread_{t-1}$	1.573**	-0.228	0.432	-1.325***	1.773***
	(0.73)	(0.50)	(0.71)	(0.46)	(0.55)
Constant	6.181	4.713	-5.775	-10.604	0.918
	(4.35)	(7.43)	(10.47)	(6.55)	(7.91)
Adjusted R-squared	0.072	0.029	0.046	0.059	0.047
Fund-Quarter Observations	10,087	10,853	10,853	10,853	10,853

Table A2: Changes in Fund Asset Allocation in Response to Redemptions: Effects of Aggregate Uncertainty using Alternative Measures

This table reports the results of quarterly panel regressions of changes in asset allocations across various asset classes, in percent, on $Outflow$ ($Inflow$), in decimal, and their interaction terms with aggregate uncertainty as follows:

$$\Delta AssetShare(\%)_{i,t} = \beta_0 + \beta_{1,1} Inflow_{i,t} \times LowVol_t + \beta_{1,2} Inflow_{i,t} \times HighVol_t$$
$$+\beta_{2,1} Outflow_{i,t} \times LowVol_t + \beta_{2,2} Outflow_{i,t} \times HighVol_t + \gamma Controls_{i,t-1} + e_{i,t}.$$

The $LowVol$ ($HighVol$) indicator variable takes a value of 1 if market volatility is below (above) historical sample median, and 0 otherwise. Panel A reports results when $LowVol$ ($HighVol$) is based on the 1-month CBOE implied volatility, Panel B based on 12-month CBOE implied volatility, and Panel C based on the implied volatility of 10-year Treasury swaptions. We winsorize fund flows at the top and bottom 1% level, and standardize the natural log of TNA and Family size of the funds relative to their means. Other control variables include Expense Ratio, Turnover, Front Load, Rear Load, Share of Retail, Log of Fund Age, Quarterly Fund Return, Credit Spreads as the difference in yields between the 10-year Treasury and investment-grade corporate bonds, Term Spreads as the difference in yields between the 10-year and 1-year Treasury notes. We include fund-fixed effects in the regressions, and cluster standard errors at the fund level, as reported in parentheses. *** 1% significance; ** 5% significance; * 10% significance.

Interaction of Volatility with Outflow	ΔCash	ΔGovernment Bonds	ΔCorporate Bonds	ΔInvestment Grade	ΔHigh Yield
Panel A: 1-Month Volatility					
$LowVol \times Outflow$	4.389***	4.469***	-5.307***	-2.080**	-2.793***
	(1.15)	(1.25)	(1.39)	(1.01)	(0.80)
$HighVol \times Outflow$	1.416	1.396	-1.979	-0.811	-0.232
	(1.97)	(1.73)	(2.07)	(1.73)	(1.24)
Panel B: 12-Month Volatility					
$LowVol \times Outflow$	4.479***	3.643**	-5.335***	-2.361**	-2.575***
	(1.20)	(1.42)	(1.56)	(1.14)	(0.87)
$HighVol \times Outflow$	1.489	2.793*	-2.793	-0.976	-0.940
	(1.69)	(1.48)	(1.75)	(1.47)	(1.08)
Panel C: Implied Volatility of Swaptions on 10-Year Treasuries					
$LowVol \times Outflow$	3.187***	3.864***	-4.429***	-1.693*	-2.023**
	(1.17)	(1.21)	(1.33)	(0.99)	(0.82)
$HighVol \times Outflow$	3.767**	2.156	-3.385	-1.607	-1.233
	(1.89)	(1.86)	(2.15)	(1.59)	(1.26)