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# Dynamic Liquidity Management by Corporate Bond Mutual Funds

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## Abstract

How do corporate bond mutual funds manage liquidity to meet investor redemptions? We show that during tranquil market conditions, these funds tend to reduce liquid asset holdings to meet redemptions, temporarily increasing relative exposures to illiquid asset classes. When aggregate uncertainty rises, however, they tend to scale down their liquid and illiquid assets proportionally to preserve portfolio liquidity. This fund-level dynamic management of liquidity appears to affect the broad financial market: Redemptions from the corporate bond fund sector lead to more corporate bond selling during high-uncertainty periods, which generates price pressures and predicts strong return reversals.

## I. 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 gross domestic product (GDP) and 40% of the global financial assets. Against the backdrop of a postcrisis 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 those funds hold, effectively leads to liquidity transformation.

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However, the liquidity transformation comes with its own risks, especially when concerns about a fund's liquidity drive its investors to the exit. Indeed, episodes of significant outflows from bond funds were observed amid elevated market volatility, such as the Taper Tantrum in 2013. Similarly, in Dec. 2015, Third Avenue Focused Credit Fund, a high-yield bond fund manager, experienced run-like investor redemptions. Unable to unwind its illiquid bond holdings immediately without taking large losses, the fund announced the suspension of investor redemptions and liquidation of the fund.[1] Such events highlight the concern that the liquidity mismatch in the open-end mutual fund industry might contribute to financial instability. In light of these developments, regulators have continued to strengthen oversight of the asset management industry. For instance, the U.S. Securities and Exchange Commission (SEC) has adopted new rules since Oct. 2016 to strengthen liquidity management practices for open-end mutual funds; in 2017, the Financial Stability Board offered several policy recommendations regarding the disclosure and implementation of liquidity risk management programs for open-end mutual funds.[2]

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 asset prices and the stability of the broad financial markets? In this article, 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 managers because they create liquidity transformation by allowing daily redemptions while investing in relatively illiquid corporate debt.[3] As a result, effective liquidity management is critical to the smooth operation and sustainable performance of these funds. To understand the economics of their liquidity management, we design empirical tests based on theories with general implications for liquidity management and with features specific to corporate bond funds.

Specifically, we focus on two broad strategies of corporate bond funds to accommodate investor redemptions. The beneficial role of using cash and liquid assets to absorb the impact of fund flows on a mutual fund's core investment portfolio is well recognized. For instance, Leland and Connor (1995) and Connor

[1]After that, it made quarterly distributions to its shareholders for more than 2.5 years, when the illiquid bond holdings were gradually liquidated. The most recent fund distribution took place on June 27, 2018. The fund's total liquidating distributions from Dec. 16, 2015, to June 27, 2018, were $5.46 per share; the fund's net asset value (NAV) was $6.46 on Dec. 9, 2015, when the fund initially announced the decision of redemption suspension. For more information on the liquidation process of Third Avenue Focused Credit Fund, see https://focusedcreditfund.com.

[2]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.

[3]The 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).

and Leland (1995) provide a structural framework for analyzing an asset manager's optimal cash policy. In their model, a manager holds cash to save on trading costs associated with investor flows in order to preserve near-term performance; however, because of the lower average return on cash, holding cash decreases the fund's expected return and increases its tracking-error variance relative to its benchmark index, which contains no cash positions. Under this setup, they show that the manager's optimal cash policy is to maintain cash balances within a certain range: When the cash balances fall within the range, it is optimal to allow cash levels to float with fund flows, playing the role of liquidity buffers. Such a practice of using cash as a liquidity buffer can easily be extended to a broader strategy of a fund using liquid asset holdings to meet investor redemptions. We refer to this strategy of horizontally cutting the fund's assets along the liquidity spectrum as a "horizontal cut."[4]

The preceding theory assumes that fund flows are completely random, exogenous to the liquidity choice of the fund manager. A growing number of recent articles, such as those by Chen, Goldstein, and Jiang (2010) and Goldstein, Jiang, and Ng (2017), however, highlight how the illiquidity of fund assets can lead to a first-mover advantage among fund investors in their redemption decisions, which generates a risk of runs on these funds. When the risk of a potential run is sufficiently high, a fund manager may find it optimal to preserve the liquidity of fund assets. In this case, the fund manager tends to scale down the fund's assets more proportionally, engaging in a "vertical cut" of fund assets to meet investor redemptions.[5]

To empirically explore these two strategies, we use detailed holdings data on a panel of 578 open-end actively managed corporate bond funds from 2002 to 2014. 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 increases their relative exposures to illiquid asset classes, such as corporate bonds. This strategy of a horizontal cut is consistent with the intention of corporate bond funds to mitigate redemptions-induced trading costs that may lower their immediate performance.

Of course, changes in a bond fund's asset allocations can be driven by both liquidity management as well as strategic portfolio management decisions. For instance, an increase in interest rates might increase the opportunity cost for bond funds to hold cash, which may be associated with a decline in their cash holdings. Similarly, widening credit spreads may enhance the attraction of corporate bonds relative to Treasury bonds, inducing bond funds to increase their allocation to corporate bonds. Our results support these conjectures. More important, we show that liquidity management continues to be an important force driving the asset allocations of corporate bond funds: The horizontal-cut strategy in response to investor redemptions is robust after controlling for credit and term spreads. In an

[4]The broad intuition of the liquidity buffer can be found in the large literature on optimal inventory and optimal cash management for business firms.

[5]This rationale can be extended to consider a more extreme case, in which fund managers could sell corporate bonds even more than the amount of investor redemptions, increasing the fund's liquidity. For our sample of corporate bonds, however, we do not find much support for this extreme version of the vertical cut strategy.

alternative specification, we include time fixed effects to absorb the time variation in aggregate economic conditions, and our main results remain similar.[6]

Our second set of results shows that the liquidation strategy to meet investor redemptions appears to be contingent on market conditions and differ across funds. In particular, we find that when aggregate uncertainty, as captured by the Chicago Board Options Exchange (CBOE) Volatility Index (VIX), rises 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 proportionally, 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 during high-uncertainty periods points to funds' aversion to increased vulnerabilities arising from higher exposures to illiquid asset classes.

Furthermore, we show that the propensity for funds to engage in a horizontal cut versus a vertical cut to meet redemption needs differs across funds. Exploiting cross-sectional heterogeneity, we find that corporate bond funds with higher funding uncertainty (higher flow volatilities), more persistent flows, and higher rear-end loads exhibit a stronger tendency to follow the vertical-cut approach. These results are intuitive because managers of corporate bond funds with higher flow volatilities and stronger flow persistence may be more worried about preserving liquidity to accommodate future investor redemptions. However, funds with higher rear-end loads may attract investors whose investment decisions are less sensitive to short-term fund performance. As such, the managers of these funds tend to be less concerned about short-term underperformance associated with asset liquidation and are thus more likely to follow a vertical-cut strategy.

In combination, these two sets of results on asset allocations suggest that corporate bond fund managers tend to trade off between short-term liquidation costs that lower the near-term fund performance and longer-term vulnerabilities arising from early depletion of liquid assets. The dynamic switch of fund liquidation strategy from a horizontal to a vertical cut amid heightened aggregate uncertainty has interesting implications. In particular, the common tendency of corporate bond funds to liquidate corporate bonds in response to investor redemptions may lead to a particularly high demand for liquidity in the corporate bond market during periods with high uncertainty. Considering the decreasing supply of liquidity when uncertainty rises (Nagel (2012)), corporate bond fund selling can generate a significant impact on the prices of corporate bonds in this situation.

Our last set of analyses examines this conjecture. We first study whether investor redemptions from the corporate bond fund sector lead to more corporate bond selling by these funds when aggregate uncertainty is high. To this end, we construct a measure of flow-implied trade for each corporate bond, assuming each fund to proportionally scale down fund assets to meet investor redemptions.

[6]In addition to individual regressions for each asset class, we use the seemingly unrelated regressions (SURs) to estimate the equations of changes in cash holdings, changes in government bonds, and changes in corporate bond holdings in one system. The results in Table A2 of the Supplementary Material lend robustness to our finding.

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For instance, for a corporate bond with 15% ownership by mutual funds,[7] if each fund receives a redemption request worth 10% of fund assets, then the outflow-implied sale of this bond amounts to 1.5% of the bond's outstanding value. We find that when the VIX is low, the flow-implied trade is statistically unrelated to the actual trade by fund managers. When the VIX is high, however, the flow-implied trade is strongly and positively related to actual trade, which is consistent with the idea that investor redemptions translate into more corporate bond selling when aggregate uncertainty is high.

More importantly, we find that investor redemptions tend to generate stronger price pressures and predict a stronger reversal of corporate bond returns during high-uncertainty periods. For example, when the VIX is 1 standard deviation above average, a 1% flow-implied selling pressure predicts an increase in the bond's abnormal return of 72.23 basis points (bps) during the subsequent quarter. These results indicate 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 article contributes to the growing literature on financial fragility and run-like behavior among investors in open-end mutual funds (e.g., Chen et al. (2010), Feroli, Kashyap, Schoenholtz, and Shin (2014), Goldstein et al. (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 article helps to improve our understanding of the interaction between fund managers' liquidity management and the behavior of fund investors, as well as the potential sources of financial instability.

Our article is naturally linked to the literature on liquidity management by asset managers. There is a large literature that studies the decisions of equity mutual funds and hedge funds to hold cash and liquid assets (see, e.g., Yan (2006), Simutin (2014), Huang (2015), and Liu and Mello (2011)), yet there is a small but growing literature on the liquidity management by fixed-income funds. Among the latter group, Jiang and Zhu (2016) examine how corporate bond funds use credit default swaps for liquidity management; Chernenko and Sunderam (2016) study the role of cash holdings in meeting investor redemptions for U.S. mutual funds; and 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 et al. (2015) and Morris et al. (2017) find that emerging-market bond funds tend to hoard cash, selling illiquid assets to increase their cash positions to meet investor redemptions. Our article examines liquidity management by U.S. corporate

[7]As of the second quarter of 2018, mutual funds as a group owned more than $2 trillion in corporate and foreign bonds, which accounted for approximately 15% of their total $13 trillion outstanding. The figures are from "Financial Accounts of the United States," page 122 (https://www.federalreserve.gov/releases/z1/20180920/z1.pdf).

bond funds beyond adjustments on cash holdings. We cover the entire fixed-income portfolios by bond funds and allow fund liquidation strategies to vary with market conditions. Our results 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. Thus, our findings help 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 and across market conditions.

Our article is also related to a strand of literature that examines the price impact on the underlying securities due to mutual fund trades.[8] Since the seminal works of Shleifer and Vishny (1992), (1997) and Coval and Stafford (2007), there is a large-consensus view that 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. Manconi, Massa, and Yasuda (2012) examine the contagion from "toxic" securitized bonds to corporate bonds during the recent financial crisis, and Cai, Han, Li, and Li (2016) study herding behavior among institutional investors in the corporate bond market. Both articles show evidence of a price impact when many institutions sell bonds at the same time. However, Hoseinzade (2017) finds no evidence for a price impact associated with mutual fund "fire sales" in the corporate bond market. Our article is among the first to identify the time-varying price impact of flows-induced mutual fund sales in the corporate bond market. Consistent with our finding, parallel work by Choi and Shin (2018) finds evidence of a price impact related to bond fund fire sales. The key distinction between our work and that of Choi and Shin (2018) lies in the focus. Our article provides a solid understanding of the economics driving fund liquidity management practices and offers in-depth and comprehensive analyses to illustrate how the trade-off between near-term fund performance and longer-horizon fund viability leads to different liquidation strategies across funds and over periods with different levels of macroeconomic uncertainties.[9]

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

## II. 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

[8]The impact arising from fund trades is not limited to asset price movements. For instance, Aslan and Kumar (2019) study the impact of forced sales of corporate bonds by financial institutions on the capital investment and product-market competitiveness of the bond issuers.

[9]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) on the sterling corporate bond market).

open-end funds accommodate the redemption requests from their shareholders on a daily basis. The provision of liquid claims makes effective liquidity management vital for open-end funds, especially those investing in illiquid asset classes, such as corporate bonds.

In this article, we focus on the strategies of corporate bond funds to meet investor redemptions.[10] Our work builds on prior articles 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 the core investment portfolio, to facilitate investor redemptions.

Broadly speaking, mutual funds can employ two strategies to meet investor redemptions. They can 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 in a "vertical cut" of their portfolios. In the first case, by resorting to liquid assets at hand, fund managers avoid an immediate and costly sale 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. Motivated by the theory discussed in the Introduction, we put forth 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, leading to increased exposure to illiquid asset classes.

Despite the benefit of preserving near-term performance, the downside of a horizontal cut is the resulting portfolio tilt toward illiquid asset classes, which increases the vulnerability of the funds to subsequent adverse shocks. As shown by Chen et al. (2010) and Goldstein et al. (2017), a fund with particularly high illiquid asset holdings is more likely to experience runs by the fund shareholders. When fund managers perceive the risk of a run to be high, 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 at a cost, they sacrifice the short-term performance in order to maintain a relatively liquid portfolio, which protects remaining shareholders from excess exposures to illiquid assets. The benefits and costs of these two strategies vary through time and across funds, which leads to the following two hypotheses.

Over time, when aggregate uncertainty rises, the payoff of illiquid risky assets becomes more volatile, and the asset illiquidity increases. As a result of strategic complementarities among investor-redemption decisions, mutual fund investors may then be particularly concerned about the illiquidity of the mutual fund assets. Indeed, Goldstein et al. (2017) show that when the VIX is high, the first-mover advantage tends to be stronger, and investor redemptions are more sensitive to the

[10]We do not consider short-term liquidity management tools, such as interfund lending within the same fund family and lines of credit, but focus on the relatively lower-frequency impact of investor redemptions on bond funds' asset-allocation decisions.

illiquidity of mutual fund assets. In our sample, we also find that higher aggregate uncertainty is associated with more volatile corporate bond fund flows. Hence, when uncertainty is high, fund managers may be more reluctant to reduce cash and liquid asset holdings to meet investor redemptions, but they prefer a vertical-cut liquidation strategy.[11] We therefore put forth our second hypothesis as follows:

*Hypothesis 2 (H2 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.

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 the flows of a fund tend to be highly persistent (investor redemptions tend to cluster in time), the manager may be less willing to increase the illiquidity of the fund portfolio following investor redemptions. Because mutual funds with higher rear-end fees may attract investors who are more focused on longer-term fund performance, the manager may be less concerned with a temporary decline in fund performance as a result of costly asset liquidation leading to investor exits. By contrast, a fund with low or no rear-end fees may attract investors who are more sensitive to temporary declines in fund performance because of transaction costs; as a result, the fund manager is more likely to use a horizontal cut to accommodate investor redemptions.[12] These discussions lead to our third hypothesis.

*Hypothesis 3 (H3 Vertical Cut: Cross-Fund Variation).* Corporate bond funds with higher flow volatility, higher persistence in flows, and higher rear-end fees are more likely to scale down their assets proportionally in response to investor redemptions, preserving the liquidity of their portfolios.

Having discussed the strategies of corporate bond funds to meet investor redemptions at the level of asset allocations, we now consider their liquidation decisions at the level of individual corporate bonds. Conditional on a fund manager's decision to liquidate corporate bonds, we hypothesize that the manager has an incentive to minimize the liquidation costs by following a liquidity pecking order:[13]

*Hypothesis 4 (H4 Liquidity Pecking Order).* Conditional on asset liquidation, more liquid corporate bonds are more likely to be liquidated.

[11] In a different setup, Bernardo and Welch (2004) show the conditions under which it is optimal for investors to liquidate illiquid assets because of fears of future liquid shocks.

[12] Although one may think that funds with high rear-end fees may attract less fickle investors and thus have lower flow volatility, empirically, we find that the correlation between rear-end fees and fund flow volatility is quite low at merely −0.06. Therefore, these two variables carry different information about investor characteristics.

[13] This is consistent with evidence from the equity market. For instance, Anand, Irvine, Puckett, and Venkataraman (2013) show that during the 2008 financial crisis, institutional trading shifts toward more liquid stocks.

A large literature is devoted to the predictability of mutual fund flows. The general message in the literature is that fund flows have a large component that is 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 between expected and unexpected flows is the degree of persistence and the resulting demand for immediacy. Because shocks in fund flows represent forecast errors, they are on average more transitory than expected flows, which are highly autocorrelated. This leads to the following hypothesis:

*Hypothesis 5 (H5 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.

In terms of market impact, if corporate bond fund managers tend to rely on cash and other liquid assets to meet investor redemptions, flows-induced selling may spread out over time, which mitigates the impact of fund selling on the corporate bond market. However, if elevated aggregate uncertainty induces many corporate bond fund managers to employ a vertical-cut liquidation strategy across different classes, flow-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 6 (H6 Price Pressure).* Corporate bonds with larger exposures to mutual fund flow-induced selling in high-uncertainty periods tend to experience larger subsequent return reversals.

## III. Sample Construction and Summary Statistics

Our sample covers the period from 2002:Q3 to 2014:Q2, 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 Center for Research in Security Prices (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. We further exclude bonds that are close to maturity (with less than 1 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 2 characters of the CRSP objective code, or a Lipper nonequity fund with an asset code “TX.” We exclude balanced funds and index funds from our sample and require a matching of CRSP bond funds with the eMAXX database. This leads

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TABLE 1
Summary Statistics

Table 1 shows the summary statistics for the characteristics of the corporate bond funds and corporate bonds in our sample from 2002:Q1 to 2014:Q2. 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 nonagency issues); quarterly fund flow (%), quarterly flow volatility (%), and first-order autoregressive coefficient (AR1) based on the last 3 years of flows; total net assets (TNA) ($millions); family size ($millions); quarterly fund return (%); fund age in years; maximum front-end and rear-end load (%); expense ratio (%); turnover (in decimal); and retail investor share (fraction of funds owned by retail investors, in decimal). Corporate bond characteristics include Roll's illiquidity (%), bid–ask spread (%), Amihud illiquidity, interquartile price range (%), abnormal quarterly return (%), credit rating, issue size ($millions), bond age (years), and coupon rate (%).

| Characteristics | Mean | Std. Dev. | P5 | P25 | P50 | P75 | P95 | *N* |
|---|---|---|---|---|---|---|---|---|
| *Fund Level* | | | | | | | | |
| Cash holdings (%) | 6.60 | 10.48 | 0.00 | 1.67 | 3.63 | 7.00 | 24.62 | 16,490 |
| % of fixed income in government bonds | 9.84 | 16.38 | 0.00 | 0.00 | 2.00 | 14.45 | 42.86 | 17,540 |
| % of fixed income in corporate bonds | 58.47 | 27.47 | 10.62 | 36.95 | 59.46 | 84.56 | 93.97 | 17,540 |
| % in investment grade | 20.79 | 22.17 | 0.00 | 1.08 | 13.83 | 35.59 | 64.53 | 17,529 |
| % in high yield | 37.72 | 36.38 | 0.00 | 4.70 | 19.77 | 81.41 | 92.15 | 17,529 |
| % of fixed income in foreign holdings | 14.34 | 14.70 | 0.00 | 5.49 | 10.45 | 17.71 | 42.14 | 17,540 |
| % of fixed income in structured products | 16.11 | 21.45 | 0.00 | 0.14 | 4.34 | 28.41 | 60.04 | 17,540 |
| % in agency issues | 8.41 | 13.54 | 0.00 | 0.00 | 1.14 | 12.45 | 36.74 | 17,540 |
| % in nonagency issues | 7.70 | 12.55 | 0.00 | 0.00 | 1.50 | 11.30 | 33.21 | 17,540 |
| Quarterly fund flow (%) | 3.80 | 15.01 | –11.27 | –3.38 | 0.53 | 6.52 | 29.74 | 19,052 |
| Quarterly fund flow volatility (%) | 8.21 | 6.76 | 1.73 | 3.76 | 6.09 | 10.52 | 22.12 | 11,066 |
| AR1 of quarterly fund flow | 0.21 | 0.34 | –0.35 | –0.05 | 0.21 | 0.47 | 0.75 | 13,941 |
| TNA($millions) | 1,245 | 3,214 | 13 | 84 | 292 | 942 | 5,888 | 19,937 |
| Family size ($millions) | 12,446 | 46,783 | 48 | 497 | 2,308 | 7,704 | 34,474 | 19,937 |
| Quarterly return (%) | 1.37 | 3.75 | –3.27 | 0.00 | 1.20 | 2.78 | 6.37 | 19,937 |
| Fund age (years) | 13.39 | 11.54 | 1.00 | 5.27 | 11.40 | 18.02 | 33.11 | 19,936 |
| Maximum rear-end load (%) | 0.50 | 0.76 | 0.00 | 0.00 | 0.01 | 1.00 | 2.00 | 19,937 |
| Maximum front-end load (%) | 0.93 | 1.33 | 0.00 | 0.00 | 0.06 | 1.76 | 3.69 | 19,937 |
| Expense ratio (%) | 0.90 | 0.35 | 0.36 | 0.66 | 0.86 | 1.11 | 1.52 | 18,785 |
| Turnover | 1.14 | 1.29 | 0.20 | 0.43 | 0.71 | 1.27 | 3.79 | 18,642 |
| Retail investor share | 0.57 | 0.42 | 0.00 | 0.06 | 0.72 | 1.00 | 1.00 | 19,936 |
| *Corporate Bond Level* | | | | | | | | |
| Roll's illiquidity (%) | 1.02 | 0.83 | 0.16 | 0.45 | 0.81 | 1.35 | 2.48 | 987,564 |
| Bid–ask spread (%) | 1.14 | 0.94 | 0.12 | 0.45 | 0.91 | 1.61 | 2.90 | 977,605 |
| Amihud illiquidity | 0.43 | 0.28 | 0.06 | 0.22 | 0.40 | 0.57 | 0.90 | 1,076,295 |
| Interquarter price range (%) | 0.72 | 0.62 | 0.06 | 0.29 | 0.56 | 0.98 | 1.84 | 1,077,158 |
| Abnormal quarterly return (%) | –0.13 | 5.04 | –6.65 | –1.33 | –0.08 | 1.23 | 6.10 | 1,077,158 |
| Credit rating | 10.68 | 3.98 | 4.33 | 7.67 | 10.67 | 14.00 | 17.00 | 1,077,158 |
| Issue size ($millions) | 1,109 | 1,325 | 250 | 500 | 750 | 1,400 | 3,000 | 1,077,158 |
| Bond age (years) | 3.10 | 2.74 | 1.00 | 1.00 | 2.00 | 4.00 | 8.00 | 1,077,158 |
| Coupon rate (%) | 6.74 | 1.98 | 3.25 | 5.60 | 6.75 | 8.00 | 10.00 | 1,077,158 |

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 the holdings of major asset classes by aggregating individual securities within the specific classes based on par value. 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 in at least one quarter in our sample period.[14] Our final sample consists of 578 unique funds, with holdings of up to approximately 6,000 corporate bonds in a given quarter.

[14]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 of the Supplementary Material.

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.[15] Within fixed-income assets, corporate bond funds on average hold 9.84% assets in government bonds; 58.47% in corporate bonds; 14% in foreign securities; and 16% in structured products, including asset-backed securities (ABSs), commercial mortgage-backed securities (CMBSs), and residential mortgage-backed securities (RMBSs).[16] The pairwise 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 TNA, winsorized at the top and bottom 1st percentiles, is 3.80% in a given quarter, with an average time-series volatility of 8.21% and a 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%.[17]

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.[18] According to practitioners, bond funds tend to pass through bond interest income to shareholders on a periodic (typically monthly) basis.[19] Fund investors may choose to automatically reinvest fund distributions back to the fund or keep the fund payouts. In the former case, our net flows variables will capture the automatic fund inflow; in the latter, interest income does not directly affect a fund's liquidity management practices. The corporate bonds in our sample are traded with an average bid–ask spread of 1.14%, Roll's illiquidity measure of 1.02%, Amihud illiquidity measure of 0.43, and interquarter price range of 0.72%. The illiquidity measures are positively correlated, with pairwise correlations ranging from 0.5 to near 0.8. Detailed definitions of the bond variables are reported in the Appendix.

## IV. 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 of how bond funds change their asset allocations amid

[15]Our cash-holdings data come from the CRSP. In the literature, different articles have used different sources for their data on cash holdings. For instance, Chernenko and Sunderam (2016) use mutual fund N-SAR filings; Choi and Shin (2018) use Morningstar. On average, the levels of cash holdings are comparable, ranging from approximately 7% to 10%.

[16]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 of asset allocations, we do not consider these two asset classes.

[17]Bond funds in general have higher portfolio turnover ratios than equity funds, as a result of, for example, the maturity of bonds, the call feature, and the attempt of fund managers to maintain their target duration of the bond portfolio.

[18]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.

[19]See, for example, https://www.fidelity.com/learning-center/investment-products/mutual-funds/tax-implications-bond-funds.

redemptions. Then we examine how bond funds liquidate individual corporate bonds to meet investor redemptions.

## A. Changes in Asset Allocation: Horizontal Versus Vertical Cuts

As discussed in Section II, 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. Conversely, 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 over time.

### 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:

$$(1)\qquad \Delta\text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 + \beta_1\text{NET\_INFLOW}_{i,t} + \beta_2\text{NET\_OUTFLOW}_{i,t} + \beta_3\text{CONTROLS}_{i,t-1} + e_{i,t},$$

where $\Delta\text{ASSET\_SHARE}(\%)_{i,t} = (\text{ASSET}_{i,t}\text{TOTAL}_{i,t}) - (\text{ASSET}_{i,t-1}\text{TOTAL}_{i,t-1})$ 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 $t$, in percent. 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.[20] For government and corporate bonds, we use the ratio of government and corporate bond holdings relative to the fund's total fixed income holdings based on par value from the eMAXX database. The advantage of using par value is to ensure that variations in the asset-allocation ratios are not driven by changes in their relative prices.

$\text{NET\_OUTFLOW}_{i,t}$ ($\text{NET\_INFLOW}_{i,t}$) equals net fund flows, in decimal, for fund $i$ during quarter $t$ if it is below (above) 0, and 0 otherwise. The regressions coefficients for NET_INFLOW and NET_OUTFLOW, $\beta_1$ and $\beta_2$, capture the effects of net investor purchases and redemptions on changes in fund asset allocation. Our focus is on $\beta_2$. The strategy of a horizontal cut of portfolios to meet investor redemptions implies a positive $\beta_2$ for liquid asset holdings such as cash and government bonds but a negative $\beta_2$ for illiquid asset holdings such as corporate

[20]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, for example, as extreme as −80% and above 100% of TNA, in the data. We impose a filter of 0 to 25% of the cash-holding level to better focus on cash holdings due to liquidity motives.

bonds. In contrast, the strategy of a vertical cut implies a 0 $\beta_2$ for both liquid and illiquid asset holdings.

The control variables include lagged fund characteristics such as fund performance, the natural logarithm 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. In one specification (regressions 1–3), we include the term and credit spreads to account for potential impact on bond fund asset allocation due to shifting bond market conditions. In another specification (regressions 4–6), we use time fixed effects to absorb the influence due to changes in aggregate economic conditions.[21] All the regressions have fund fixed effects, and we cluster standard errors by fund.

We note that although fund flows and changes in asset allocation are measured over the same quarter in the regressions, our results are not driven by the effects of reverse causality, namely, that fund shareholders react to the changes in the asset allocation of the fund. This is because fund shareholders do not observe the fund's portfolio composition on a contemporaneous basis, but with a lag. The SEC requires mutual funds to disclose their portfolio composition within 2 months.

Table 2 shows that $\beta_2$ 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, regressions 4–6 show that a 1-standard-deviation increase in redemptions is associated with a contemporaneous decline in CASH/TNA of $4.226\% \times 15\% = 63$ bps,[22] a decline in the weight on government bonds out of fixed income holdings of $2.952\% \times 15\% = 444$ bps, and an increase in the weight on corporate bonds of $3.218\% \times 0.15 = 48$ bps. 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.

## 2. Aggregate Uncertainty and Fund Liquidation Strategy

The choice of bond fund liquidating strategies may depend on aggregate uncertainty. In particular, when aggregate uncertainty rises, the payoff of illiquid risky assets becomes more volatile, and the asset illiquidity increases. Because the strategic complementarities in redemption decisions among mutual fund investors is exacerbated by the asset illiquidity, mutual fund investors may then be particularly concerned about the illiquidity of the mutual fund assets. As shown by

[21]The results are similar across the two specifications. We follow the second specification for the remainder of the article unless otherwise specified.

[22]To assess the impact on the *amount* of cash holdings due to redemptions, in an unreported analysis (available from the authors), we estimate an alternative panel regression: $\frac{\Delta \text{CASH}_{i,t}}{\text{TNA}_{i,t-1}}(\%) = \beta_0 + \beta_1 \text{NET\_INFLOW}_{i,t} + \beta_2 \text{NET\_OUTFLOW}_{i,t} + \beta_3 \text{CONTROLS}_{i,t-1} + e_{i,t}$, The estimated coefficient indicates that \$1 in outflow is associated with a reduction in cash holdings of approximately 8 cents. Note that this specification helps to capture how fund managers handle outflows dollar by dollar and is the focus of Chernenko and Sunderam (2016). It is different from our focus on how funds' asset-allocation decisions are influenced by investor redemptions.

TABLE 2

Changes in Fund Asset Allocation in Response to Redemptions

Table 2 reports the results of panel regressions of changes in the holdings of various asset classes, in percent, on NET_OUTFLOW (NET_INFLOW), in decimal, at the quarterly frequency, specified as follows:

$$\Delta \text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 + \beta_1 \text{NET\_INFLOW}_{i,t} + \beta_2 \text{NET\_OUTFLOW}_{i,t} + \gamma \text{CONTROLS}_{i,t-1} + e_{i,t}.$$

We winsorize fund flows at the top and bottom 1% levels and standardize the natural logarithm of the total net assets (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(FUND_AGE), and QTR_FUND_RETURN. In regressions 1–3, we include TERM_SPREAD and CREDIT_SPREAD; in regressions 4–6, we include time fixed effects. All regressions have fund fixed effects, and we cluster standard errors by fund, as reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

| | ΔCASH | ΔGOV_BONDS | ΔCORPORATE_BONDS | ΔCASH | ΔGOV_BONDS | ΔCORPORATE_BONDS |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| NET_INFLOW | 0.639 | 0.969*** | 0.345 | 0.798* | 1.020*** | 0.447 |
| | (0.47) | (0.36) | (0.52) | (0.47) | (0.36) | (0.51) |
| NET_OUTFLOW | 3.311*** | 3.323*** | –4.184*** | 4.226*** | 2.952*** | –3.218*** |
| | (1.03) | (1.05) | (1.17) | (1.04) | (1.07) | (1.19) |
| $\log(\text{TNA})_{t-1}$ | –0.209 | –0.146 | 0.13 | –0.205 | –0.166 | 0.231* |
| | (0.15) | (0.12) | (0.13) | (0.15) | (0.12) | (0.13) |
| $\log(\text{FAMILY\_SIZE})_{t-1}$ | 0.013 | –0.286* | –0.381** | –0.019 | –0.265* | –0.453** |
| | (0.16) | (0.15) | (0.19) | (0.16) | (0.15) | (0.19) |
| $\text{EXPENSE\_RATIO}_{t-1}$ | 42.112 | –38.613 | –48.414 | 41.564 | –46.985 | –18.019 |
| | (37.44) | (36.18) | (45.82) | (37.48) | (37.42) | (46.46) |
| $\text{TURNOVER}_{t-1}$ | 0.037 | –0.203*** | 0.103* | 0.036 | –0.212*** | 0.117** |
| | (0.07) | (0.06) | (0.06) | (0.07) | (0.06) | (0.06) |
| $\text{FRONT\_LOAD}_{t-1}$ | –0.029 | –0.153* | 0.035 | –0.049 | –0.162* | 0.047 |
| | (0.06) | (0.08) | (0.10) | (0.06) | (0.08) | (0.10) |
| $\text{REAR\_LOAD}_{t-1}$ | –0.036 | 0.004 | 0.07 | –0.086 | –0.018 | 0.117 |
| | (0.08) | (0.07) | (0.08) | (0.09) | (0.07) | (0.08) |
| $\text{SHARE\_OF\_RETAIL}_{t-1}$ | –0.12 | 0.348 | –0.106 | –0.23 | 0.319 | –0.052 |
| | (0.27) | (0.28) | (0.34) | (0.27) | (0.28) | (0.33) |
| $\log(\text{FUND\_AGE})_{t-1}$ | 0.07 | 0.322*** | –0.13 | 0.346 | 0.414** | –0.506** |
| | (0.13) | (0.11) | (0.14) | (0.21) | (0.16) | (0.24) |
| $\text{QTR\_FUND\_RETURN}_{t-1}$ | –0.046*** | 0.016*** | –0.021** | –0.017 | –0.032** | 0.043** |
| | (0.01) | (0.01) | (0.01) | (0.02) | (0.01) | (0.02) |
| $\text{TERM\_SPREAD}_{t-1}$ | –0.064** | 0.130*** | –0.049 | | | |
| | (0.03) | (0.03) | (0.03) | | | |
| $\text{CREDIT\_SPREAD}_{t-1}$ | –0.108*** | –0.046 | 0.280*** | | | |
| | (0.04) | (0.04) | (0.05) | | | |
| CONSTANT | –0.082 | –0.483 | –0.014 | 7.259 | –0.324 | 0.371 |
| | (0.47) | (0.48) | (0.57) | (4.43) | (0.63) | (0.77) |
| Time fixed effects | No | No | No | Yes | Yes | Y |
| Adj. $R^2$ | 0.056 | 0.016 | 0.023 | 0.064 | 0.024 | 0.04 |
| Fund-quarter obs. | 13,868 | 15,627 | 15,627 | 13,868 | 15,627 | 15,627 |

Goldstein et al. (2017), when the VIX is high, the first-mover advantage tends to be stronger, and investor redemptions are more sensitive to the illiquidity of mutual fund assets. Moreover, we find in our sample that higher aggregate uncertainty is associated with more volatile corporate bond fund flows. Hence, in situations of heightened uncertainty, the increased concern about the risk of investor runs can induce a stronger preference by fund managers for a vertical-cut liquidation strategy to meet investor redemptions, which is our Hypothesis 2. To test it, we add interaction terms of market volatility with contemporaneous net flows to equation (1):

$$(2) \quad \Delta\text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 + \beta_{1,1}\text{NET\_INFLOW}_{i,t} \times \text{LOW\_VOL}_{i,t} + \beta_{1,2}\text{NET\_INFLOW}_{i,t} \times \text{HIGH\_VOL}_{i,t} + \beta_{2,1}\text{NET\_OUTFLOW}_{i,t} \times \text{LOW\_VOL}_{i,t} + \beta_{2,2}\text{NET\_OUTFLOW}_{i,t} \times \text{HIGH\_VOL}_{i,t} + \beta_3\text{CONTROLS}_{i,t-1} + e_{i,t},$$

where LOW_VOL (HIGH_VOL) 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.[23] We use CBOE 3-month implied volatility to define the state of aggregate uncertainty. All controls in equation (1) are also included here. Term and credit spreads, as well as the indicator variable HIGH_VOL, are included to capture the potential impact on asset allocation due to shifting in bond-market conditions. The regressions also include fund fixed effects, and standard errors are clustered at the fund level.

We report the results in Table 3. For brevity, we present estimates only 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: A 1-standard-deviation increase in redemptions over normal periods is associated with a decline in proportional cash holdings of $4.430\% \times 15\% = 66$ bps, a decline in the relative weight on government securities out of fixed income holdings of $3.741\% \times 15\% = 56$ bp, and an increase in relative corporate bond holdings of $4.941\% \times 15\% = 74$ bps. However, over periods of elevated aggregate uncertainty, the interaction terms of NET_OUTFLOW with HIGH_VOL 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 the LOW_VOL (HIGH_VOL) indicators accordingly.[24] For instance, for the downside-volatility-based indicator, LOW_VOL (HIGH_VOL) takes a value of 1 if the expected downside volatility is above (below) its historical median, and 0 otherwise. Panels B and C in Table 3 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.

[23]We also use the whole sample mean and median levels of the VIX to define high- and low-VIX periods, and the results remain similar.

[24]At each time point, the prices of a set of 3-month put and call options on the Standard & Poor's (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, LOW_VOL (HIGH_VOL) used here is the cumulative distribution function of a price decline (rise) of 10% or more. It can be interpreted that the risk-neutral price of a binary option that pays $1 if the S&P 500 declines (rises) by 10% or more in 3 months, and 0 otherwise. Other cutoff numbers, including a 5% and a 15% decline (rise), were considered and yield similar results.

TABLE 3

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

Table 3 reports the results of quarterly panel regressions of changes in asset allocations across various asset classes, in percent, on NET_OUTFLOW (NET_INFLOW), in decimal, and their interaction terms with aggregate uncertainty, as follows:

$$\Delta \text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 + \beta_{1,1}\text{NET\_INFLOW}_{i,t} \times \text{LOW\_VOL}_t + \beta_{1,2}\text{NET\_INFLOW}_{i,t} \times \text{HIGH\_VOL}_t + \beta_{2,1}\text{NET\_OUTFLOW}_{i,t} \times \text{LOW\_VOL}_t + \beta_{2,2}\text{NET\_OUTFLOW}_{i,t} \times \text{HIGH\_VOL}_t + \gamma\text{CONTROLS}_{i,t-1} + e_{i,t}.$$

The LOW_VOL (HIGH_VOL) indicator variable takes a value of 1 if market volatility is below (above) the historical sample median, and 0 otherwise. Panel A reports results when LOW_VOL (HIGH_VOL) is based on the 3-month Chicago Board Options Exchange (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% levels and standardize the natural logarithm of the total net assets (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(FUND_AGE), QTR_FUND_RETURN, TERM_SPREAD, CREDIT_SPREAD, and HIGH_VOL. We include fund fixed effects in the regressions and cluster standard errors at the fund level, as reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

| Interaction of VOLATILITY with NET_OUTFLOW | ΔCASH | ΔGOV_BONDS | ΔCORPORATE_ BONDS |
|---|---|---|---|
| *Panel A. 3-Month Volatility* | | | |
| LOW_VOL × NET_OUTFLOW | 4.430*** | 3.741*** | –4.941*** |
| | (1.16) | (1.24) | (1.41) |
| HIGH_VOL × NET_OUTFLOW | 1.457 | 2.402 | –2.503 |
| | (1.91) | (1.70) | (2.01) |
| *Panel B. 3-Month Downside Volatility* | | | |
| LOW_VOL × NET_OUTFLOW | 4.168*** | 2.997*** | –5.676** |
| | (1.22) | (1.48) | (1.60) |
| HIGH_VOL × NET_OUTFLOW | 2.261 | 3.371** | –2.614 |
| | (1.63) | (1.42) | (1.65) |
| *Panel C. 3-Month Upside Volatility* | | | |
| LOW_VOL × NET_OUTFLOW | 4.322*** | 4.785*** | –5.303**** |
| | (1.14) | (1.23) | (1.41) |
| HIGH_VOL × NET_OUTFLOW | 1.611 | 0.874 | –1.864 |
| | (1.98) | (1.75) | (2.10) |

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

## 3. Heterogeneity Across Funds

When balancing between the desire to preserve near-term performance and the desire to conserve liquidity reserves against future liquidity shocks, fund managers may factor in fund attributes. 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 by fund managers to preserve the liquidity of their portfolios. 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 losing investors when trading off near-term performance for portfolio liquidity preservation. As a result, managers of those funds are more likely to pursue a vertical cut to meet investor redemptions, which forms our Hypothesis 3.

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

$$\begin{aligned}(3)\quad \Delta \text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 &+ \beta_{1,1}\text{NET\_INFLOW}_{i,t} \times \text{LOW\_CHAR}_{i,t} \\ &+ \beta_{1,2}\text{NET\_INFLOW}_{i,t} \times \text{HIGH\_CHAR}_{i,t} \\ &+ \beta_{2,1}\text{NET\_OUTFLOW}_{i,t} \times \text{LOW\_CHAR}_{i,t} \\ &+ \beta_{2,2}\text{NET\_OUTFLOW}_{i,t} \times \text{HIGH\_CHAR}_{i,t} \\ &+ \beta_3\text{CONTROLS}_{i,t-1} + e_{i,t},\end{aligned}$$

where LOW_CHAR and HIGH_CHAR 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 gauge the potential investment horizon, we use maximum rear-load fees. For each fund characteristics, we construct a LOW_CHAR (HIGH_CHAR) 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.[25]

Table 4 shows the results, which support Hypothesis 3. Panel A shows that in the regression explaining changes in a fund's proportional cash holdings, the coefficient for NET_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 dummy variable of low fund flow volatility, 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, NET_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 proportionally to meet investor redemptions, engaging in vertical cuts of their portfolios. Panels B and C show results for funds with varying degrees of flow persistence and rear-end loads, which provide similar support for Hypothesis 3.

## 4. Replenishing Liquid Assets Following Investor Redemptions?

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 portfolios. In this subsection, we explore this conjecture.

[25]We also consider specifications without fund fixed effects, which generate results consistent with those presented in Table 4.

TABLE 4

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

Table 4 reports the results of quarterly panel regressions of changes in asset allocations across various asset classes, in percent, on NET_OUTFLOW (NET_INFLOW), in decimal, and their interaction terms with fund characteristics, as follows:

$$\Delta\text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 + \beta_{1,1}\text{NET\_INFLOW}_{i,t} \times \text{LOW\_CHAR}_{i,t} + \beta_{1,2}\text{NET\_INFLOW}_{i,t} \times \text{HIGH\_CHAR}_{i,t} + \beta_{2,1}\text{NET\_OUTFLOW}_{i,t} \times \text{LOW\_CHAR}_{i,t} + \beta_{2,2}\text{NET\_OUTFLOW}_{i,t} \times \text{HIGH\_CHAR}_{i,t} + \gamma\text{CONTROLS}_{i,t-1} + e_{i,t}.$$

The LOW_CHAR (HIGH_CHAR) 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 the maximum rear-end fee. We winsorize fund flows at the top and bottom 1% levels and standardize the natural logarithm of the total net assets (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(FUND_AGE), and QTR_FUND_RETURN. We include fund and quarter fixed effects in the regressions and cluster standard errors at the fund level, as reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

| Interaction of Fund Characteristics with NET_OUTFLOW | ΔCASH | ΔGOV_BONDS | ΔCORPORATE_BONDS |
|---|---|---|---|
| *Panel A. Flow Volatilities* | | | |
| LOW_CHAR × NET_OUTFLOW | 6.181*** | 5.847*** | –7.496*** |
| | (1.63) | (1.67) | (2.09) |
| HIGH_CHAR × NET_OUTFLOW | 3.517*** | 1.687 | –1.331 |
| | (1.28) | (1.30) | (1.42) |
| *Panel B. Flow Persistence* | | | |
| LOW_CHAR × NET_OUTFLOW | 5.088*** | 3.966*** | –3.533** |
| | (1.33) | (1.47) | (1.60) |
| HIGH_CHAR × NET_OUTFLOW | 3.077* | 1.802 | –2.601 |
| | (1.58) | (1.52) | (1.74) |
| *Panel C. Maximum Rear-End Loads* | | | |
| LOW_CHAR × NET_OUTFLOW | 7.166*** | 5.715*** | –2.975* |
| | (1.50) | (1.53) | (1.73) |
| HIGH_CHAR × NET_OUTFLOW | 0.85 | –0.341 | –3.519** |
| | (1.48) | (1.47) | (1.56) |

In particular, to test whether investor redemptions are associated with subsequent adjustments in a fund's liquid asset holdings, we estimate the following quarterly panel regressions:

$$(4)\quad \Delta\text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 + \beta_1\text{NET\_INFLOW}_{i,t} + \beta_2\text{NET\_OUTFLOW}_{i,t} + \beta_3\text{NET\_INFLOW}_{i,t-1} + \beta_4\text{NET\_OUTFLOW}_{i,t-1} + \gamma\text{CONTROLS}_{i,t-1} + e_{i,t}.$$

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 $\beta_2$ and $\beta_4$ in Table 5. Our results show that based on the estimates on $\beta_2$, the previously documented horizontal-cut pattern persists. The estimates on $\beta_4$ suggest that when reacting to last-quarter redemptions, managers are likely to increase their liquid asset holdings, such as cash and government bonds. These results corroborate the conjecture that managers engage in dynamic liquidity management, replenishing their liquidity reserves following investor redemptions.

TABLE 5

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

Table 5 reports the results of quarterly panel regressions of changes in asset allocations across various asset classes, in percent, on NET_OUTFLOW (NET_INFLOW), in decimal, in the previous quarter:

$$\Delta \text{ASSET\_SHARE}(\%)_{i,t} = \beta_0 + \beta_1 \text{NET\_INFLOW}_{i,t} + \beta_2 \text{NET\_OUTFLOW}_{i,t} + \beta_3 \text{NET\_INFLOW}_{i,t-1} + \beta_4 \text{NET\_OUTFLOW}_{i,t-1} + \gamma \text{CONTROLS}_{i,t-1} + e_{i,t}.$$

We winsorize fund flows at the top and bottom 1% levels and standardize the natural logarithm of the total net assets (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(FUND_AGE), and QTR_FUND_RETURN. We include fund fixed effects in the regressions and cluster standard errors at the fund level, as reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

| | ΔCASH | ΔGOV_BONDS | ΔCORPORATE_BONDS |
|---|---|---|---|
| NET_OUTFLOW | 5.007*** | 3.993*** | –3.988*** |
| | (1.16) | (1.09) | (1.29) |
| $\text{NET\_OUTFLOW}_{t-1}$ | –2.867*** | –3.542*** | 2.531** |
| | (1.03) | (1.10) | (1.21) |

## B. 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 liquidation 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, which forms Hypothesis 4.

We examine Hypothesis 4 in two ways. First, we estimate a logit regression at a quarterly frequency as follows:

$$(5)\quad \text{logit}(\text{SOLD})_{i,t} = \beta_0 + \beta_1 \text{NET\_OUTFLOW}_{i,t} + \beta_2 \text{ILLIQUIDITY}_{i,t} + \beta_3 \text{NET\_OUTFLOW}_{i,t} \times \text{ILLIQUIDITY}_{i,t} + \beta_4 \text{NET\_INFLOW}_{i,t} + \beta_5 \text{NET\_INFLOW}_{i,t} \times \text{ILLIQUIDITY}_{i,t} + \text{CONTROLS}_{i,t-1} + e_{i,t}.$$

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's measure, the Amihud measure, and the interquartile price range. NET_OUTFLOW and NET_INFLOW are defined as before. Because security liquidation decisions can be affected by both fund and security 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,[26] credit ratings, log of issue size,

[26]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 residual returns after taking out the effect of the aforementioned bond features. Details of bond abnormal returns are provided in the Appendix.

log of age, and coupon rate. The regressions also include fund fixed and quarter fixed effects, with standard errors clustered at the fund level. For brevity, in Table 6, we only show results for the key variables.

Panel A shows that the coefficient for NET_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 NET_OUTFLOW and ILLIQUIDITY 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 4.

Second, as an alternative test specification, we repeat the previous analysis using an ordinary least squares (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.

## C. 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) for equity funds and Goldstein et al. (2017) for bond funds). The broad conclusion is that past performance and past flows have substantial predictive power for future fund flows. Do corporate bond fund managers adopt different schemes to accommodate expected and unexpected flows? We hypothesize that a key distinction between expected and unexpected flows is the degree of their persistence. Because shocks in fund flows represent forecast errors, they are on average more transitory than expected flows, which are highly autocorrelated. This leads to our Hypothesis 5.

To examine this hypothesis, we first decompose fund flows into expected and unexpected components. For each fund over a 3-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 reestimate equations (1) and (5), replacing realized flows with expected and unexpected flows in corresponding terms while keeping all the 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 of Table 7 shows a clear pattern that corporate bond fund managers tend to meet unexpected and expected investor redemptions differently. In particular, consistent with Hypothesis 5, 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

TABLE 6

**Security Liquidation: Liquidity Pecking Order**

Panel A of Table 6 reports the results of quarterly logit regressions of selling a corporate bond on NET_OUTFLOW (NET_INFLOW), in decimal; bond illiquidity; and their interaction terms. If a corporate bond holding is reduced over quarter *t*, the left-hand side (LHS) is entered as 1, and 0 otherwise. Panel B reports the quarterly ordinary least squares (OLS) pooled regressions of the percentage of bonds sold on NET_OUTFLOW (NET_INFLOW), in decimal; bond illiquidity; and their interaction terms. We winsorize fund flows at the top and bottom 1% levels. Corporate bond illiquidity is measured by bid–ask spread, Roll's illiquidity, Amihud illiquidity, and interquartile 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 logarithm of the 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. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

| | Bid–Ask | Roll | Amihud | IQR |
|---|---|---|---|---|
| *Panel A. Logit Model on Sales Indicator* | | | | |
| | Sales Indicator (Logit) | | | |
| NET_OUTFLOW | –3.876***<br>(0.33) | –3.922***<br>(0.34) | –3.927***<br>(0.34) | –3.939***<br>(0.34) |
| NET_INFLOW | –0.756***<br>(0.16) | –0.762***<br>(0.16) | –0.753***<br>(0.16) | –0.753***<br>(0.16) |
| ILLIQUIDITY | –0.017*<br>(0.01) | 0.025**<br>(0.01) | –0.019**<br>(0.01) | 0.014<br>(0.01) |
| NET_OUTFLOW × ILLIQUIDITY | 0.234*<br>(0.13) | 0.282**<br>(0.12) | 0.046<br>(0.12) | 0.252**<br>(0.12) |
| NET_INFLOW × ILLIQUIDITY | –0.015<br>(0.07) | 0.025<br>(0.07) | –0.013<br>(0.05) | 0.032<br>(0.07) |
| Bond-fund-quarter obs. | 761,586 | 769,331 | 840,245 | 840,963 |
| *Panel B. OLS Model on Percentage Sold* | | | | |
| | Percentage Sold (OLS) | | | |
| NET_OUTFLOW | –0.272***<br>(0.04) | –0.273***<br>(0.04) | –0.271***<br>(0.04) | –0.270***<br>(0.04) |
| NET_INFLOW | –0.015<br>(0.01) | –0.015<br>(0.01) | –0.014<br>(0.01) | –0.015<br>(0.01) |
| ILLIQUIDITY | –0.002**<br>(0.00) | 0.002*<br>(0.00) | –0.002**<br>(0.00) | 0.001<br>(0.00) |
| NET_OUTFLOW × ILLIQUIDITY | 0.032**<br>(0.02) | 0.015<br>(0.02) | 0.031**<br>(0.01) | 0.02<br>(0.01) |
| NET_INFLOW × ILLIQUIDITY | –0.006<br>(0.01) | 0.005<br>(0.01) | –0.004<br>(0.00) | –0.004<br>(0.00) |
| Adj. $R^2$ | 0.069 | 0.07 | 0.068 | 0.068 |
| Bond-fund-quarter obs. | 704,699 | 712,507 | 778,431 | 779,114 |

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 5 that corporate bond funds tend to rely more on liquid assets to accommodate unexpected outflows than expected redemptions.

TABLE 7

## Responses to Expected and Unexpected Redemptions

Panel A of Table 7 reports the results of quarterly panel regressions of changes in various asset class holdings, in percent, on expected and unexpected NET_OUTFLOW (NET_INFLOW), in decimal. The control variables are similar to Table 2. Panel B reports the quarterly logistic regressions of bond selling and ordinary least squares (OLS) regressions of the percentage of bonds sold as in Table 6. All control variables are included. For both panels, we include fund and quarter fixed effects and standard errors clustered at the fund level, as reported in parentheses. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

*Panel A. Changes in Asset Allocations in Response to Redemptions*

| | ΔCASH | ΔGOV_ BONDS | ΔCORPORATE_BONDS |
|---|---|---|---|
| EXP_NET_OUTFLOW | 1.695<br>(1.54) | 0.864<br>(1.58) | 1.014<br>(1.59) |
| UNEXP_NET_OUTFLOW | 2.470***<br>(0.92) | 2.817***<br>(0.81) | –2.580***<br>(0.99) |

*Panel B. Security Liquidation*

| | Sales Indicator (Logit) | | | | | Percentage Sold (OLD) | | |
|---|---|---|---|---|---|---|---|---|
| | Bid–Ask | Roll | Amihud | IQR | Bid–Ask | Roll | Amihud | IQR |
| EXP_NET_OUTFLOW | –1.393**<br>(0.64) | –1.329**<br>(0.65) | –1.364**<br>(0.65) | –1.365**<br>(0.65) | 0.007<br>(0.07) | 0.012<br>(0.07) | 0.011<br>(0.07) | 0.013<br>(0.07) |
| UNEXP_NET_OUTFLOW | –3.120***<br>(0.34) | –3.138***<br>(0.34) | –3.161***<br>(0.34) | –3.167***<br>(0.34) | –0.181***<br>(0.04) | –0.177***<br>(0.04) | –0.180***<br>(0.04) | –0.179***<br>(0.04) |
| EXP_NET_OUTFLOW × ILLIQUIDITY | –0.113<br>(0.21) | –0.189<br>(0.21) | 0.07<br>(0.21) | –0.162<br>(0.18) | 0.003<br>(0.02) | 0.001<br>(0.02) | 0.039*<br>(0.02) | –0.004<br>(0.02) |
| UNEXP_NET_OUTFLOW × ILLIQUIDITY | 0.289**<br>(0.13) | 0.397***<br>(0.13) | 0.024<br>(0.11) | 0.294**<br>(0.12) | 0.027**<br>(0.01) | 0.02<br>(0.01) | 0.016<br>(0.01) | 0.013<br>(0.01) |

## D. Robustness Tests and Further Discussions

### 1. Robustness

We conduct a number of robustness tests regarding fund liquidity management practices, and the results are reported in the Supplementary Material. 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% holdings in corporate bonds out of the total fixed-income positions at all times. The results, as shown in Table A1 in the Supplementary Material, remain qualitatively similar.

Second, we use a different empirical methodology to estimate the impact of outflows on bond fund asset allocations. In particular, we consider the possibility that changes in the allocations to different asset classes may be jointly determined, and residuals from individual regressions may be correlated across equations. To address this issue, we use the SUR approach to jointly estimate equation (1) for allocations to cash, government bonds, and corporate bonds. The results are reported in Table A2 in the Supplementary Material, which shows a pattern similar to that using our baseline approach.

Third, we consider alternative measures of aggregate uncertainty, including the expected stock market VIX measured over 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 LOW_VOL and HIGH_VOL indicator variables based on the implied volatility of S&P 500 index options with different maturities to evaluate how aggregate uncertainty at different horizons affects the reaction of corporate bond fund managers to investor redemptions. Panels A and B of Table A3 in the Supplementary Material show that the results are qualitatively similar for short-term and long-horizon implied volatilities.[27] We also consider information from the bond market to capture the evolution of aggregate uncertainty, using the implied volatility of swaptions on 10-year Treasury bonds. The results in Panel C of Table A3 provide further support to our finding that when uncertainty is elevated, corporate bond funds tend to scale down their assets proportionally, maintaining their allocations between liquid and illiquid asset classes to preserve the liquidity of their portfolios.

Fourth, we investigate whether bond retirement may affect the liquidity management practices of corporate bond funds. To this end, we construct two variables, %BOND_RETIRE1 and %BOND_RETIRE4, measured as the fractions of bonds in a given fund that will mature within the next 1 and 4 quarters, and include them in the control variable set for equation (1). Table A4 in the Supplementary Material shows that our results are robust. In particular, consistent with Table 2, $\beta_2$ is positive and statistically significant for liquid asset classes, such as cash and government bonds, but it is negative and statistically significant for corporate bonds with similar magnitudes.

### 2. Further Discussions on the Switch of Liquidation Strategies

So far, our results suggest that corporate bond fund managers tend to trade off between short-term liquidation costs and longer-term vulnerabilities arising from

[27] The expected volatilities from 1-month to 12-month horizons strongly comove in our sample period, with pairwise correlations above 94%. The high correlation could be the reason why our tests do not reveal their potential differential impact on liquidity management.

the depletion of liquid assets; they switch from a horizontal-cut approach to a vertical-cut approach amid heightened aggregate uncertainties. The switch, however, may be due to funds generally falling short of cash during stressful, volatile times. In other words, could it be possible that the cash holdings of corporate bond funds may fall to a low level when uncertainty is high? To explore the plausibility of this alternative explanation, we first fit a panel regression of cash levels on fund characteristics, as in columns 1–4 of Table A5 in the Supplementary Material, following Chernenko and Sunderam (2016). The fitted value is taken as the estimate of the expected level of cash holdings using the specification in column 2, and the residual is taken as the abnormal level of cash holdings. We then regress the abnormal cash holdings on the VIX, and the results are shown in column 5 of Table A5. Column 5 shows a positive relation between the VIX and abnormal cash holdings, suggesting that when the VIX is above average, bond funds tend to hold more cash than expected, rather than hold an abnormally low level of cash as conjectured by the alternative explanation. This result can also be interpreted as supportive evidence for an increasing level of desired cash holdings during volatile times, which further provides a rationale for funds' switching from a horizontal cut to a vertical cut to preserve liquidity at such times.

Could it still be possible that our results of funds switching to a vertical cut may be driven by a subset of funds that run out of cash at such times? To address this concern, we repeat our analyses in Table 2 using a smaller sample of funds with sufficient cash reserves, defined as those whose last-quarter cash holdings plus expected within-quarter flows are greater than 0. If this subgroup also follows a vertical-cut approach in high-VIX periods, it would refute the idea that our results are driven by funds with insufficient cash and forced into corporate bond liquidation. The results, reported in Table A6 in the Supplementary Material, show a pattern consistent with our baseline results: In this subset of funds with sufficient cash, funds tend to use a horizontal cut to meet investor redemptions when uncertainty is low, but they still switch to a vertical cut when uncertainty is high.

To further strengthen the argument that the switch from a horizontal cut to a vertical cut during high-VIX periods reflects a deliberate choice driven by economic trade-off, we explore the flip side of the coin and investigate whether there are negative consequences for funds deviating from such practices. We identify a subset of funds that follow a horizontal-cut strategy during high-VIX periods, defined as those experiencing declines in relative shares of cash holdings but increases in corporate bond exposures at such times. We find that approximately 17% of funds fall into that category. More importantly, we find that such funds tend to experience larger outflows and smaller inflows over the subsequent quarter than the rest. In particular, these funds on average experience 0.55% more outflows over the subsequent quarter than other funds, and the difference is statistically significant. These results suggest that a horizontal-cut strategy amid high aggregate uncertainty renders a fund more vulnerable to investor runs.

## V. Fire-Sale Externality of Corporate Bond Fund Trading

We have established that corporate bond funds tend to switch their liquidation strategy from a horizontal cut during tranquil market conditions to a vertical cut

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amid heightened aggregate uncertainty. Whereas 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 more aggressively at times of stress, which, at the *aggregate* level, may adversely affect the corporate bond market. In this section, we examine Hypothesis 6: Trading pressures from bond funds at times of stress can lead to temporary movements in the prices of corporate bonds, which are followed by return reversals.

To conduct these tests, we first examine whether investor redemptions from the corporate bond fund sector induce stronger selling of corporate bonds when uncertainty is high. To this end, we devise a new measure of flow-implied trade. We assume that a 1% outflow in quarter $t$ leads a fund $f$ to liquidate its assets by 1%, and then for a given bond $i$, we aggregate all the flow-implied trades by $F$ corporate bond funds that hold this bond:

$$\text{FLOW\_IMPLIED\_TRADE}_{i,t} = \frac{\sum_{f=1}^{F}\left(\text{FLOW}_{f,t} \times \text{HOLDINGS}^{i}{}_{f,t}\right)}{\text{ISSUE\_OUTSTANDING}_{i,t}}.$$

In essence, this measure sets a benchmark case to evaluate how flows into and out of the corporate bond fund sector translate into corporate bond trading by these funds.[28] In situations where the strategy of a horizontal cut is prevalent, we would expect funds to rely on their liquidity buffers to accommodate investor flows; as such, the association between flow-implied and actual trades would be weak during these periods. In situations where the vertical cut is prevalent, we would expect flow-implied trades to have a stronger association with actual trades. To empirically examine these conjectures, we perform the following panel regressions:

$$\begin{aligned}(6)\qquad \text{ACTUAL\_TRADE}_{i,t} = \frac{\sum_{f=1}^{F}\Delta\text{HOLDINGS}^{i}{}_{f,t}}{\text{ISSUE\_OUTSTANDING}_{i,t}} &= \beta_0 \\ &+ \beta_1\text{FLOW\_IMPLIED\_TRADE}_{i,t-k} \\ &+ \beta_2\text{FLOW\_IMPLIED\_TRADE}_{i,t-k} \\ &\times \text{VIX}_{t-k} + e_{i,t},\end{aligned}$$

where $k = 0, 1, 2, 3$, and the VIX is standardized to have a mean of 0 and a standard deviation of 1. The regressions include time fixed effects, and the standard errors are clustered by bond. In these regressions, our focus is on the case $k = 0$.

The results in column 1 of Table 8 show that when aggregate uncertainty is low, with a standardized VIX value equal to 0, the relation between flow-implied and actual trades is statistically indistinguishable from 0. When aggregate uncertainty spikes up, however, the relation between flow-implied and actual trades is

[28]One way to interpret the measure is that after a fund manager makes portfolio decisions in quarter $t$ and observes investor redemptions in quarter $t$, the manager cuts a slice of the portfolio on a pro rata basis to meet investor redemptions. The numerator of the flow-implied trade reflects the dollar amount based on the par value sold for a particular bond, and the denominator reflects the total par value of the bond outstanding.

TABLE 8

Flow-Implied Trade and Actual Trade

Table 8 reports the quarterly panel regression results of actual trades in corporate bonds on a measure of flow-induced trades as well as its interaction term with the Volatility Index (VIX). Actual trade is defined by changes in the par value of the bonds held by mutual funds in our sample during quarter $t$. Flow-induced trade is defined as $\frac{\sum_{f=1}^{F}(\text{FLOW}_{f,t}\times\text{HOLDINGS}_{f,t}^{i})}{\text{ISSUE\_OUTSTANDING}_{i,t-1}}$. For ease of interpretation, we standardize the VIX to have a mean of 0 and a standard deviation of 1. Quarter-fixed effects are controlled for in the regression. The standard errors, reported in parentheses, are clustered at the bond level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

| | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| $\text{FLOW\_IMPLIED\_TRADE}_t$ | 0.023 | | | |
| | (0.09) | | | |
| $\text{FLOW\_IMPLIED\_TRADE} \times \text{VIX})_t$ | 0.528*** | | | |
| | (0.09) | | | |
| $\text{FLOW\_IMPLIED\_TRADE}_{t-1}$ | | –0.183*** | | |
| | | (0.06) | | |
| $(\text{FLOW\_IMPLIED\_TRADE} \times \text{VIX})_{t-1}$ | | 0.230*** | | |
| | | (0.05) | | |
| $\text{FLOW\_IMPLIED\_TRADE}_{t-2}$ | | | –0.003 | |
| | | | (0.05) | |
| $(\text{FLOW\_IMPLIED\_TRADE} \times \text{VIX})_{t-2}$ | | | –0.049 | |
| | | | (0.04) | |
| $\text{FLOW\_IMPLIED\_TRADE}_{t-3}$ | | | | –0.093 |
| | | | | (0.08) |
| $(\text{FLOW\_IMPLIED\_TRADE} \times \text{VIX})_{t-3}$ | | | | –0.077 |
| | | | | (0.06) |
| Adj. $R^2$ | 0.026 | 0.018 | 0.009 | 0.008 |
| Bond-quarter obs. | 212,957 | 190,069 | 172,887 | 157,639 |

substantially stronger and statistically significant. Consistent with our preceding analyses of liquidity management practices, these results indicate that corporate bond funds as a group indeed show a stronger tendency to liquidate corporate bonds in response to investor redemptions when aggregate uncertainty is high. In the subsequent quarters, this selling pressure tends to wane, with the regression coefficients tending toward 0.

If flows-induced trading pressure from mutual funds affects bond prices, we would expect those bonds to experience an initial decline in prices, with 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 a stronger price impact on corporate bonds. We use the following panel regressions to examine these conjectures:

$$\text{(7)}\quad \text{ABNORMAL\_RETURN}_{i,t} = \beta_0 + \beta_1\text{FLOW\_IMPLIED\_TRADE}_{i,t-k} + \beta_2\text{FLOW\_IMPLIED\_TRADE}_{i,t-k} \times \text{VIX}_{t-k} + e_{i,t},$$

where $\text{ABNORMAL\_RETURN}_{i,t}$ is computed as the raw bond return, in percent, 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, and $k = 1,2,3$.

TABLE 9

Flow-Implied Trade and Future Bond Returns

Table 9 reports the quarterly panel regression results of quarterly abnormal bond returns, in percent, on a measure of flow-induced trades as well as its interaction term with the Volatility Index (VIX), specified as follows: $\text{ABNORMAL\_RETURN}_{i,t} = \beta_0 + \beta_1 \text{FLOW\_IMPLIED\_TRADE}_{i,t-k} + \beta_2 \text{FLOW\_IMPLIED\_TRADE}_{i,t-k} \times \text{VIX}_{t-k} + e_{i,t}$. 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. Flow-induced trade is defined as $\frac{\sum_{f=1}^{F} (\text{FLOW}_{f,t} \times \text{HOLDINGS}^{i}{}_{f,t})}{\text{ISSUE\_OUTSTANDING}_{i,t-1}}$.

| | 1 | 2 | 3 |
|---|---|---|---|
| $\text{FLOW\_IMPLIED\_TRADE}_{t-1}$ | –29.542*** | | |
| | (3.75) | | |
| $(\text{FLOW\_IMPLIED\_TRADE} \times \text{VIX})_{t-1}$ | –42.693*** | | |
| | (6.66) | | |
| $\text{FLOW\_IMPLIED\_TRADE}_{t-2}$ | | –15.285*** | |
| | | (2.44) | |
| $(\text{FLOW\_IMPLIED\_TRADE} \times \text{VIX})_{t-2}$ | | –29.375*** | |
| | | (4.04) | |
| $\text{FLOW\_IMPLIED\_TRADE}_{t-3}$ | | | –8.424*** |
| | | | (2.27) |
| $(\text{FLOW\_IMPLIED\_TRADE} \times \text{VIX})_{t-3}$ | | | –8.954*** |
| | | | (3.12) |
| Adj. $R^2$ | 0.008 | 0.007 | 0.006 |
| Bond-quarter obs. | 190,069 | 172,887 | 157,639 |

The results in Table 9 show a strong predictive power of flow-implied trades to predict future bond returns, especially when the VIX is high. In terms of magnitudes, when the VIX is 1 standard deviation above average, a 1% increase in flow-implied selling predicts an increase in bond returns of 72.23 bps ($= -1\% \times (-29.54 - 42.69)\%$) in the subsequent quarter, 44.65 bps in quarter $t+2$, and 17.37 bps in quarter $t+3$.[29]

As a robustness analysis, we also follow Coval and Stafford (2007) and construct a measure of trading pressure based on realized fund trades conditional on large fund flows:

$$\text{PRESSURE}_{i,t} = \frac{\sum_{f=1}^{F} \left( \begin{array}{c} \text{BUY}^{i}{}_{f,t} \mid \text{FLOW}_{f,t} > 90\text{th percentile} - \text{SELL}^{i}{}_{f,t} \mid \text{FLOW}_{f,t} \\ < 10\text{th percentile} \end{array} \right)}{\text{ISSUE\_OUTSTANDING}_{i,t-1}}.$$

This measure captures the difference between purchases and sales of bonds by mutual funds that experience extreme inflows and outflows, with a large negative

[29]In Table A7 of the Supplementary Material, we use portfolio sorts and find qualitatively similar patterns of stronger return reversals following flow-implied trading in periods with high aggregate uncertainty. In terms of magnitudes, we find that over high-VIX periods, during the sorting quarter $t$, bonds in the highest-selling-pressure quintile (based on FLOW_IMPLIED_TRADE) underperform those in the lowest-selling-pressure quintile by 0.33% per quarter. Such price pressures appear to be temporary and start to wane from the next quarter; the return spread between the highest- and lowest-selling-pressure quintiles turns into a positive 0.26% per quarter during quarter $t+1$ and continues to rebound to reach a cumulative abnormal return spread of 0.48% by the end of quarter $t+2$. By contrast, there is no clear pattern of return reversals over low-VIX quarters.

TABLE 10

Coval and Stafford (2007) Price Pressure and Future Bond Returns

Table 10 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 the Volatility Index (VIX), specified as follows: $\text{ABNORMAL\_RETURN}_{i,t} = \beta_0 + \beta_1 \text{PRESSURE}_{i,t-k} + \beta_2 \text{PRESSURE}_{i,t-k} \times \text{VIX}_{t-k} + e_{i,t}$. 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

$$\frac{\sum_{f=1}^{F}\left(\text{BUY}^{i}{}_{f,t}|\text{FLOW}_{f,t} > 90\text{th percentile} - \text{SELL}^{i}{}_{f,t}|\text{FLOW}_{f,t} < 10\text{th percentile}\right)}{\text{ISSUE\_OUTSTANDING}_{i,t-1}}.$$

The pressure variable is winsorized at the top and bottom 1% levels. For ease of interpretation, we standardize the VIX to have a mean of 0 and a standard deviation of 1. Fund and quarter fixed effects are controlled for in the regression. The standard errors, reported in parentheses, are clustered at the fund level. *, **, and *** indicate statistical significance at the 10%, 5%, and 1% levels, respectively.

| | 1 | 2 | 3 |
|---|---|---|---|
| $\text{PRESSURE}_{t-1}$ | –24.625*** | | |
| | (4.79) | | |
| $(\text{PRESSURE} \times \text{VIX})_{t-1}$ | –28.026*** | | |
| | (8.05) | | |
| $\text{PRESSURE}_{t-2}$ | | –9.365** | |
| | | (4.50) | |
| $(\text{PRESSURE} \times \text{VIX})_{t-2}$ | | –21.890*** | |
| | | (6.85) | |
| $\text{PRESSURE}_{t-3}$ | | | –5.774 |
| | | | (4.65) |
| $(\text{PRESSURE} \times \text{VIX})_{t-3}$ | | | –13.945** |
| | | | (6.47) |
| Adj. $R^2$ | 0.006 | 0.006 | 0.006 |
| Bond-quarter obs. | 190,069 | 172,887 | 157,639 |

(positive) value indicating strong selling (buying) pressure. With it, we perform a regression similar to equation (7).

The results in Table 10 show a consistent pattern. For instance, during the period when the VIX is at its mean level, a 1% selling pressure (PRESSURE = 1%) on a bond in a given quarter predicts an increase in the abnormal return on that bond of 24.62 bps in the next quarter. When the VIX is 1 standard deviation above average, the magnitude of the return reversal more than doubles: A 1% selling pressure predicts an increase in the bond's abnormal return of 52.64 bps during the subsequent quarter. The coefficient for the interaction between PRESSURE and the standardized VIX is large and statistically significant in the quarter $t+2$ and tapers off subsequently. To summarize, the results in this section 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 from excess temporary movements in bond prices.

## VI. Conclusion

In this article, we have explored the liquidity management practices of 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. At times when uncertainty is elevated, however, fund managers tend to follow a liquidation strategy of scaling down assets more proportionally across liquid and illiquid asset classes, thereby preserving 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 may have unintended consequences for financial instability. In particular, corporate bonds that are subject to 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. Overall, our article indicates that it is beneficial to consider the interplay of mutual fund 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 interest and coupon payments. In particular, the raw return for bond $i$ in quarter $t$ is calculated as

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

where $P_{i,t}$ is bond $i$'s price at the start of quarter $t$, $I_{i,t}$ is accrued interest, and $D_{i,t}$ is an indicator for 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, S&P'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 illiquidity. We use TRACE transaction data to calculate various daily illiquidity measures for each bond. We then take the within-quarter average of the daily measures to get the quarterly illiquidity measure.

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

$$\text{ILLIQUIDITY}_{i,d}^{\text{AMIHUD}} = \frac{1}{N_{i,d}} \sum_{j=1}^{N_{i,d}} \sqrt{\frac{\left| \frac{P_{i,d}^{j} - P_{i,d}^{j-1}}{P_{i,d}^{j-1}} \right|}{Q_{i,d}^{j}}}, \tag{9}$$

   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; a larger Amihud value implies a larger price impact of trades at a given size (Kyle (1985)).

(b) The implied bid–ask spread based on Roll (1984), defined as follows:

$$\text{ILLIQUIDITY}_{i,d}^{\text{ROLL}} = 2\sqrt{-\text{cov}\left(\Delta P_{i,d}^{j}, \Delta P_{i,d}^{j-1}\right)}. \tag{10}$$

(c) The interquartile price range, an indirect measure of the bid–ask spread using the interquartile range (IQR) of trade prices, defined as the difference between the 75th and 25th percentiles of prices for the day:

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

(d) The realized bid–ask spread, which is the difference between the weighted-average dealer ask prices and weighted-average dealer bid prices. Dealer ask (bid) prices are prices at which dealers buy from (sell to) customers. TRACE identifies each trade to be either "dealer buy from customer," "dealer sell to customer," or "interdealer." The weights are the par volume of trades.

## Supplementary Material

To view supplementary material for this article, please visit http://dx.doi.org/10.1017/S0022109020000460.

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