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Asset Managers and Financial Instability: Evidence of Run Behavior and Run Incentives in Corporate Bond Funds

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Asset Managers and Financial Instability:

Evidence of Run Behavior and Run Incentives in Corporate Bond Funds

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Abstract

U.S. financial regulators are currently scrutinizing open-end corporate bond mutual funds due to their immense size, risk-taking behavior, and vulnerability to dramatic outflows. Bond funds may present systemic risk, as investor redemptions trigger asset sales and redemption costs that only impact remaining investors in the fund. Liquidation lag and mark-to-market lag translate these redemption costs into run incentives. This paper first tests for run-like behavior in corporate bond funds and then tests for the underlying run incentive, measured by the NAV impact. I find that illiquid bond funds are significantly more sensitive to past performance than liquid funds and experience up to 43.6% more outflows given a 1% decrease in returns. Furthermore, net flows in bond funds held primarily by institutional investors are less sensitive to performance but more sensitive to illiquidity than flows in funds held by retail investors, suggesting that institutional bond funds may be more vulnerable to runs. Finally, using a novel dataset, I proxy for the illiquidity of a fund's underlying bonds and quantify the run incentive. Given 10% net outflows, funds that have insufficient cash levels and hold bonds of illiquidity 3-5 deviations from the mean experience a significant decrease in NAV of about 34-49 basis points. This paper contributes to the mutual fund and financial regulation literature by offering new empirical evidence of run behavior and run incentives in corporate bond funds.

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Contents

1 Introduction

Since the U.S. Financial Crisis of 2007-2009, large asset managers have drawn increased scrutiny from regulators due to their immense size, risk-taking behavior, legal structure, and potential for large fluctuations in flows. This paper focuses on the propensity of asset managers, specifically open-end corporate bond mutual funds, to exhibit run behavior and measures the underlying run incentive. Because runs are typically associated with leveraged financial institutions such as banks, it may seem unusual to consider unleveraged institutions, such as mutual funds, as capable of runs. Much research has centered on the traditional commercial bank run model proposed by Diamond and Dybvig (1983), where banks rely on short-term deposits and are susceptible to widespread withdrawals. Yet, the same theory, that institutions using short-term financing to make long-term investments are vulnerable to runs, has powerful implications for asset managers as well. Chen, Goldstein, and Jiang (2010) first showed empirical evidence of run behavior in equity funds. Recently, Feroli, Kashyap, Schoenholtz, and Shin (2014) examine aggregate data of bond fund flows during the taper tantrums and conjecture that potential run incentives may exist for bond funds, magnifying the ability of unleveraged financial institutions to contribute to financial instability. Although research has pointed to the existence of run incentives in asset managers, there have been few if any empirical studies focusing on corporate bond funds. This paper is one of the first to offer empirical evidence that corporate bond funds exhibit run incentives.

History has shown the systemic importance of fund vehicles in propagating crises. The recent financial crisis was partly fueled by unprecedented runs on money market mutual funds (MMMFs), as market panic prompted investors in these funds to rapidly redeem shares. According to the Investment Company Institute, MMMFs experienced a record $539 billion of net outflows in 2009 (compared to $1.3 trillion of net inflows during 2007-2008), the largest amount of redemptions for MMMFs ever. Interestingly, outflows from money market funds became inflows into bond funds, as investors sought higher yields in a low-interest rate environment. While the U.S. mutual fund industry suffered total net outflows of $150 billion in 2009, bond funds experienced record high net inflows of $376 billion, 13.4x the $28 billion inflows into bond funds in 2008. This dramatic flow of capital into bond funds has continued since the crisis. While total U.S. mutual fund assets grew 35% from $11.1 trillion to $15 trillion (half of the total worldwide) during 2009-2013, bond fund assets grew 49% from $2.2 trillion in 2009 to $3.3 trillion in 2013[1]. Data from EPFR show that since 2005, over $766 billion of capital has flowed into U.S. bond funds, more flows into bond funds than flows into any other asset. Additional data from Morningstar show that, from Jan 2008 to April 2013, worldwide net flows into bond funds were 4x those into equity funds, $2 trillion compared to $500 billion.

The growth of assets in bond funds and the dramatic increase in flows make potential runs on bond funds important to financial stability. This paper aims to first identify run behavior, specifically in corporate bond funds, and then quantify the magnitude of run incentives. I argue that run incentives arise from two key mechanisms, liquidation lag and mark-to-market lag, and test for liquidation lag in the data. As noted in Chen, Goldstein, and Jiang (2010), because open-end bond funds are publically traded vehicles where investors can buy and redeem shares at daily NAV, redemptions produce negative externalities. Redemptions trigger trading costs and other related costs as fund managers rebalance the portfolio, and these redemption costs only impact remaining investors in the fund. Liquidation lag and mark-to-market lag create run incentives by reflecting these redemption costs in the fund's NAV over time rather than instantaneously post-

[1] Investment Company Institute (ICI) Factbook 2010 (23-34) and 2014 (27)

redemption, creating a "lagged" pricing effect, described in more detail in Chapter 3.2. Liquidation lag occurs when, post-redemption, a fund gradually sells assets in order to replenish its cash reserves. For example, consider a bond fund *A*. If *A* holds 10% cash and experiences 5% outflows, *A* meets its redemption demands by using 5% cash but must later sell bonds to replenish its 10% cash target. However, *A* does not instantaneously sell 5% of its assets but rather *gradually* sells in the short-term. By selling gradually, *A* avoids fire sale losses on sub-optimal asset prices. Thus, redemption costs only gradually hit *A*'s NAV over time, as *A* sells assets to replenish its 10% cash target. Similarly, mark-to-market lag arises when, post-redemption, illiquid assets *held* by bond fund *A*, but highly correlated with assets *sold* by *A*, are marked-to-market over time. Because the majority of corporate bonds do not trade daily or even monthly, these bonds are not fully marked-to-market like stocks. Upon a sale of a bond, it is highly possible that some market information is not fully reflected in the prices of other similar bonds, until perhaps in the future when those bonds trade and are fully marked-to-market. Illiquid bonds may have stale prices. These lag mechanisms produce negative externalities on the fund's remaining investors by imposing future downward pressure on NAV. Intuitively, given an economic shock, if investor *J* knows that investor *K*'s redemption today will negatively impact the value of *J*'s shares tomorrow, *J* has an incentive to redeem today as well. Thus, large redemptions introduce incentives for investors to run.

My results show statistically significant evidence of run behavior and run incentives in corporate bond funds. I first test for run behavior by measuring the effect of illiquidity on a fund's flow-performance sensitivity. In other words, given poor prior performance, illiquid funds should experience significantly greater outflows than liquid funds. When using excess category return (see Chapter 4) to proxy for prior performance, illiquid bond funds experience up to

43.6% more outflows than liquid funds, given a 1% decrease in prior performance. While this relationship holds for both institutional and retail bond funds, I find that institutional funds are on average more sensitive to illiquidity than retail funds but less sensitive to performance, evidence that institutional funds may be more susceptible to runs.

Lastly, I measure the liquidity of a fund's underlying bonds to quantify the underlying run incentive. Funds that hold very illiquid bonds are expected to experience greater liquidation lag and greater downward pressure on NAV. Additionally, funds that do not hold enough cash reserves are expected to suffer greater run incentives due to fire sales and more severe liquidation lag. I find that funds holding very illiquid bonds as well as little cash are indeed several times more sensitive to outflows than funds holding liquid bonds and sufficient cash. Given 10% net outflows, funds with insufficient cash and holding bonds of illiquidity 3 deviations from the mean experience a significant decrease in NAV of roughly 34 basis points. This NAV impact increases to about 49 basis points when illiquidity increases to 5 deviations. These results provide insight into how illiquid holdings and low cash reserves may amplify runs in bond funds during economic downturns and encourage regulation and policy discussion on how to effectively mitigate runs in bond funds and better ensure financial stability.

2 Literature Review

Recent theoretical work points to asset managers, and more generally, unleveraged financial institutions as potential sources of instability. Feroli, Kashyap, Schoenholtz, and Shin (2014) study the taper tantrum in the summer of 2013 and show evidence of bond funds disrupting financial markets. During low-interest environments, bond funds engage in excessive risk-taking by purchasing riskier assets in order to obtain higher returns and outperform peers. This reaching for yield phenomenon has been shown to exist for insurers and is believed to manifest in bond funds as well (Becker and Ivashina, 2013). However, during a period of monetary policy tightening, such as QE tapering, bond funds experience a dramatic and sharp reversal, sparking a feedback loop with heavy outflows, price declines, and more outflows. Feroli, et. al. (2014) conjecture that this feedback loop triggers massive outflows and is amplified by run incentives.

Research has also highlighted the ability of bond funds to produce contagion effects, transmitting shocks from toxic assets to otherwise healthy assets and propagating crises. Manconi, Massa, and Yasuda (2012) show that bond funds amplified the effects of the financial crisis by spreading contagion from securitized bonds to corporate bonds. Many bond funds held both securitized and corporate bonds during the crisis, and upon realizing their securitized assets had gone sour, decided to first sell their more liquid corporate bonds. This off-loading of assets led to widened yield spreads in the corporate bond market. Additionally, funds with high volatility in flows liquidated a larger amount of corporate bonds, adding to the contagion. During a crisis, run incentives may lead to dramatic outflows that can transmit and worsen contagion.

While the risk-taking and trading behavior of bond funds may contribute to financial instability, large-scale redemptions can also have unintended and damaging consequences on credit supply. Chernenko and Sunderam (2013) show that money market mutual funds

(MMMFs) that took excessive risks by lending to risky Eurozone banks experienced severe outflows in mid-2011 during the sovereign debt crisis. These large outflows forced MMMFs to cut lending, affecting both Eurozone and non-Eurozone client banks. They find that creditworthy non-Eurozone banks had their credit supply indirectly exposed to risky Eurozone banks because they were financed by the same MMMF. Thus, excess risk-taking serves as an unintended negative externality to banks with the same MMMF funding source. Because corporate bond funds are vital institutional lenders to businesses and governments, harmful runs may significantly reduce credit available to corporations seeking to raise investment-grade and/or high-yield debt.

However, there has been little empirical research addressing the question of whether bond funds exhibit incentives for potential runs. Feroli et al. (2014) study run behavior by looking at aggregate flow data and analyzing the flow-return relationship for fixed-income funds. They find that upon an unexpected monetary policy shock, funds may experience large outflows that can decrease returns, such that flows affect prices. Similarly, Cohen and Shin (2002) found that during frenzied trading periods, declines in prices lead to more sales and thus further price declines. These results show that decreasing returns and high levels of asset sales can amplify one another and create a feedback loop that worsens shocks and creates potential run behavior. This amplification mechanism suggests that bond funds may be subject to dramatic outflows that can drive further redemptions, fueling incentives for investors to run. A better understanding of the relationship between fund flows and run incentives can aid policymakers to assess risks associated with monetary policy and provide regulatory guidance to control dramatic outflows.

3 Background, Theory, and Hypotheses

This section introduces additional background, develops a theory for the mechanisms that generate run incentives, and proposes hypotheses that follow.

3.1 Background

An open-end corporate bond mutual fund is a professionally managed pool of capital, drawn from institutional and/or retail investors, that invests in corporate bonds- debt securities issued by businesses that pay interest at specified time intervals. An open-end fund is specifically characterized by its legal structure that allows investors to buy and sell shares in and out of the fund on any given day. A redemption is a withdrawal of capital when an investor sells shares at NAV i.e. the daily closing price per share. Because investors can redeem shares on any day, redemptions impose significant direct and indirect costs to funds. Direct costs arise from trades that rebalance portfolio holdings, including commissions, bid-ask spreads, taxes on capital gains, and other transaction costs. Edelen (1999) looks at equity mutual fund data and finds these costs to be substantial; redemption-driven trades have an average transaction cost of 2.2%, which can lower a fund's excess return by 1.4%. Indirect costs may also arise from downward price pressure on existing assets as a result of flow-triggered sales. For example, selling a large amount of a technology bond may lead to price declines in comparable technology bonds still held by the fund. Additionally, it is important to note that redemption costs only impact remaining investors in the fund. In other words, the price redeeming investors receive *excludes* any redemption costs. This follows from the structure of open-end funds, since NAV is calculated only once per day at the close of that day's trading. An investor who redeems shares at the opening of trading will receive the NAV calculated at market close. Thus, *present* NAV does not reflect *future* redemption costs. Only on the next day can the fund begin adjusting its portfolio to account for the previous day's outflows.

The notion of liquidity is continuously emphasized throughout this paper. Intuitively, liquidity is a measure of how easily an asset can be sold for cash at the fair market price without losing value. Liquidity can be defined as the loss incurred when an individual buys an asset and then instantaneously sells that asset. Illiquid assets include homes and other types of real estate, private equity, etc. while liquid assets include cash, treasury securities, etc. Therefore, liquidity is closely related to risk; assets that are extremely risky such as high-yield bonds tend to be illiquid while assets that are generally safe such as commercial paper, repo, and treasuries tend to be liquid. In this paper, liquidity is measured using a bond's bid-ask spread, following the intuition above. The bid-ask spread is the difference between the lowest price proposed by a seller and the highest price offered by a buyer. A bond's bid-ask spread is directly proportional to illiquidity, such that large bid-ask spreads tend to be correlated with high levels of illiquidity.

Additionally, bond funds may retain liquid cash and treasury holdings that help the fund dampen the magnitude of redemption costs. For example, a fund with 5% cash on-hand has capital available to satisfy outflows less than or equal to 5%, without the need for immediate fire sales. However, it's important to realize that many bond funds are unable to hold substantial amounts of cash. First, the highly competitive mutual fund industry incentivizes funds to hold a minimum amount of cash, as funds aim to use that cash to invest in riskier assets that help the fund boost returns, attract additional capital, and earn more fees. Therefore, a fund sometimes may not have enough cash reserves to fully satisfy redemption requests. Second, and most importantly, even if a fund retains substantial cash holdings, that fund must still liquidate assets post-redemption in order to replenish its cash reserves. In other words, all else equal, a fund with

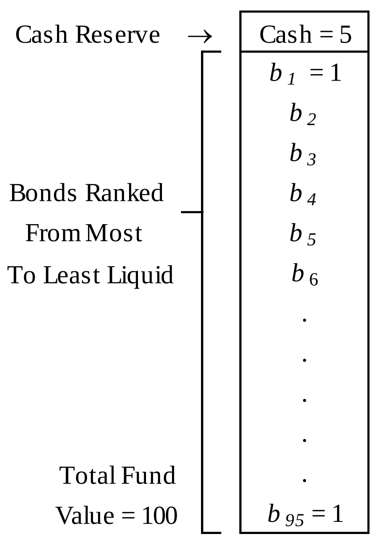
5% cash holdings can fully satisfy 3% of net outflows, but will still need to sell bonds in the short-term to replenish its 5% cash target. Allowing the cash balance to remain depleted at 5 – 3 = 2% highly increases the risk of more damaging fire sales in the next period.

3.2 Theory

Chapter 3.2.1 focuses on the bond fund run story and the intuition for the run mechanisms: liquidation lag and mark-to-market lag. Chapter 3.2.2 introduces a simplified theoretical model that formally defines liquidation lag.

3.2.1 Run Mechanisms

Figure A: Intuition for Liquidation and Mark-to-market Lag



Scenario at t_1	At time t_1	At time t_2	
Redemptions = 3	Cash = 2	$b_1,\ldots, b_3$ liquidated	**
Redemptions = 6	Cash = 0 & b_1 firesold*	$b_2,\ldots, b_6$ liquidated	***

Notes:
*fire sale of b_1 → redemption costs borne by remaining investors at t_2
**gradual liquidation
***faster gradual liquidation, since Cash = 0

**Figure not drawn to scale

a. Liquidation Lag

Liquidation lag characterizes a fund’s gradual sale of assets, so that present NAV does not fully reflect redemption costs. Because the fund only *gradually* liquidates assets in the immediate short-term, the fund’s NAV “lags” by failing to fully incorporate these future costs. In other words, expected NAV tomorrow is lower than NAV today, as redemption costs are realized upon bond sales tomorrow.

As an example, consider Figure A above. The vertical column depicts a fund's assets with a total value of 5 in cash and 95 in bonds (b_1 to b_{95}). Each bond has a value of 1, so that total holdings value equals 100. The bonds are ordered from most to least liquid, so that b_1 is the most liquid and b_{95} is the least liquid. Ranking assets in order of liquidity is important because bond funds sell their most liquid assets first, as shown in Manconi, Massa, and Yasuda (2012). Consider the scenario at t_1 with redemptions = 3. The fund meets redemptions using cash reserves and cash gets depleted to 5 – 3 = 2. In order to replenish that cash, the fund must sell bonds $b_1,\ldots,b_3$ in time t_2. The illiquidity discounts and transaction costs related to the short-term selling of $b_1,\ldots,b_3$ generate liquidation lag and run incentives that hit the fund's NAV at t_2. The fact that bonds are *gradually* sold exactly generates the run incentive. This effect is defined formally in equation (4) in the theoretical model below. Next consider the scenario at t_1 with redemptions = 6. A fund *H* meets these redemptions using all its cash reserves, and cash gets depleted to 5 – 5 = 0. Additionally, *H* must fire-sale bond b_1 to get the extra value of 1 to meet redemption demands of 6. Furthermore, *H* must sell bonds $b_2,\ldots,b_6$ in time t_2 to fully replenish its cash reserve of 5. In this scenario, *H* experiences even greater run incentives due to more severe liquidation lag from bonds $b_2,\ldots,b_6$. Because *H* is left with 0 cash post-redemption, *H* experiences "faster" liquidation lag because it must quickly recoup its cash balance or else remain vulnerable to additional outflows that would surely prompt fire sales. Alternatively, consider a fund *W* with cash reserves = 20, but in the same scenario with redemptions = 6. Although *W* experiences liquidation lag from gradually selling 6 bonds, *W* has a remaining cash buffer of 14 (since 20 – 6 = 14) and does not have the risk, present in *H*, of more redemptions leading to fire sales. In other words, *W* can comfortably take more time to replenish its cash holdings because *W* still has a large cash reserve, whereas *H* has cash = 0 and needs to replenish its cash very quickly. The increased speed at which *H* experiences liquidation lag likely results in asset sales at worse illiquidity discounts, producing a greater negative impact on NAV at t_2 and thus a greater run incentive. In summary, *H*'s fire sale of bond b_1 followed by more severe liquidation lag on bonds $b_2,\dots,b_6$ impose large costs borne by the fund's remaining investors at t_2. This effect is defined formally in equation (8) in the model below.

b. Mark-to-market Lag

Because a large percentage of bonds do not trade on a daily or even monthly basis, the prices of many illiquid bonds are not efficiently marked-to-market, unlike prices of stocks that are marked-to-market almost instantaneously. Insurance firms, some of the largest and most prominent institutional investors in corporate debt, are known to use a buy-and-hold strategy for many corporate bond issuances, compounding the lack of trading in corporate bonds. Mark-to-market lag characterizes a pricing lag for very illiquid bonds in a fund's portfolio that may not have all the latest market information reflected in their prices due to a lack of trading. Therefore, expected decreases in those bond prices are not adequately reflected in the fund's NAV.

Again, consider the example in Figure A. The fund experiences redemptions = 3, so that the fund must sell bonds $b_1,\dots,b_3$ in order to replenish its cash reserves. Assume that the most illiquid bond b_{95} is highly correlated with the most liquid bond b_1 (for example based on industry, size, and/or geography). In a perfectly efficient market, the price of b_{95} should instantaneously reflect all market information related to the sale of b_1. However, assuming bond b_{95} is the most illiquid and doesn't trade, its price may be adjusted based on the fund's matrix pricing model but still may not fully reflect updated and complete market information from the sale of b_1, creating a subtle pricing lag. In other words, the prices of illiquid bonds are less likely to fully internalize market information than liquid bonds due to a lack of trading. Therefore, mark-to-market lag creates future negative pressure on NAV. Lastly, it is important to note that mark-to-market lag is unshared by equity funds that hold stocks, which trade daily or monthly at worst. Although this paper empirically tests for liquidation lag rather than mark-to-market lag, it is important to recognize that mark-to-market lag generates a similar run incentive; present NAV does not completely internalize future costs that occur in expectation.

3.2.2 Model

The following model highlights the effect of liquidation lag and importance of building a sufficient cash buffer. The key takeaways from the model are: 1) when funds have enough cash to meet redemptions, they gradually sell assets to replenish cash holdings and 2) when funds run out of cash to meet redemptions, they fire sell assets to make up the difference and then gradually sell assets, but at a faster pace, to fully replenish their depleted cash holdings.

Consider investors holding shares in a fund, such that the sum of total shares equals 1 and the value of an investor's shares is also the percentage of the fund the investor owns. An investor cannot hold a negative number of shares. The initial NAV (Net Asset Value) or price per share equals 1. The fund's AUM, or assets under management, equals the total shares outstanding multiplied by the NAV. Formally, $AUM = Total\ Shares \cdot NAV$.

Consider a two-period model where the fund generates a gross return R_1 , where $R_1 > 0$ at t_1. A fraction s of investors redeems shares, where $0 \le s < 1$ (assuming the fund cannot go bankrupt). As explained in the background section above, a fund's investors may only redeem at daily closing NAV, so that all redeeming investors receive the same price upon redemption. Therefore, each redeeming investor at t_1 receives R_1, and the sum of total outflows equals sR_1. Given redemptions, a fund can satisfy redemption requests using 1 or more of the following 3 methods, in order of highest to lowest preference: 1) inflows, 2) cash/treasury reserves, and/or 3) proceeds from asset sales. Let *c* represent the percent cash that the fund must hold at discrete times t_1 and t_2 , where $0 \le c \le 1$, and I_1 represent inflows at t_1, where $I_1 = R_1 \cdot n$ (*n* represents new fund shares purchased). If $sR_1 \le I_1$, the fund can conveniently pay off redeeming investors by just using its new inflows. If $I_1 < sR_1 \le c$, outflows are greater than inflows, and the fund will sell highly liquid cash/treasury securities at an assumed cost of 0 to satisfy redemptions. However, if $I_1 + c < sR_1$, the fund does not have enough inflows and cash reserves to meet redemption demands and must immediately sell assets at fire-sale prices. In summary, there are two scenarios given outflows: 1) $sR_1 - I_1 \le c$ and 2) $sR_1 - I_1 > c$. In scenario 1, net outflows $sR_1 - I_1$ are less than or equal to cash *c*, so that redemptions may be satisfied by inflows, cash reserves, or both. In scenario 2, net outflows are greater than cash reserves, and the fund must fire-sell assets to secure enough cash to pay redeeming investors. Thus, scenario 2 can be simplified as $sR_1 - I_1 = c + f$, where *f* equals the proceeds from fire sales and $f \ge 0$.

Finally, before solving, it is important to note two key details. First, from above, it is assumed that a fund maintains an exogenous cash reserve percentage *c* of AUM in times t_1 and t_2. For example, consider a high-yield bond fund that holds risky junk bonds and keeps 5% cash/treasury reserves to satisfy redemptions and avoid damaging fire sales. This model assumes that the high-yield fund must maintain its 5% cash target for all periods in the future. Although it is useful to model an endogenous and dynamic cash target (since funds may want to slightly alter their cash holdings at different times to optimize returns), using an exogenous cash reserve *c* is helpful in explaining the economic intuition for run incentives in this paper. Additionally, this approach is not entirely unrealistic, since it is often strategic for funds to maintain their target cash balance; allowing cash holdings to deplete over time greatly increases the risk of large and harmful fire sales upon an economic shock.

Second, there is an important key difference between a bank run and mutual fund run that makes it challenging to solve for an equilibrium strategy. In the classic Diamond and Dybvig (1983) bank run model, along with other bank run models over the past few decades, customers withdraw their deposits at a fixed value i.e. a deposit of 1 in the bank still has a value of 1 (plus any interest) upon redemption. However, in a mutual fund run model, investors do not redeem at a fixed value but rather at a floating NAV, which fluctuates based on performance, net flows, and other factors. This difference poses an obstacle that appears throughout the literature, and several studies solve for equilibriums under the assumption that NAV remains fixed. Nevertheless, my purpose is to reveal front-running incentives to show evidence of a run incentive, rather than find a closed-form solution. In other words, as long as a mechanism creates a gap between expected future NAV and present NAV, current investors have an incentive to run and outside market players have an incentive to front-run the NAV. Therefore, I model scenarios 1 and 2 from above and analyze comparative statics.

In scenario 1, at time t_1, $sR_1 - I_1 \leq c$ so that cash reserves are sufficient to satisfy net outflows. The fund has total AUM of $R_1 - sR_1 + I_1$, total shares of $1 - s + \frac{I_1}{R_1}$, and $NAV_{t_1} = \frac{R_1 - sR_1 + I_1}{1 - s + \frac{I_1}{R_1}} = R_1$. At time t_2, the fund must replenish its cash reserves and maintain its target cash/treasury percentage c. The fund must satisfy the cash requirement constraint

$$R_1 \cdot c = c - (sR_1 - I_1) + A(1 - \lambda) \tag{1}$$

where A equals the value of assets to be sold for cash and $0 \leq \lambda < 1$ represents the level of illiquidity of the fund's assets A. Intuitively, a fund holding highly illiquid bonds will need to sell more bonds to get the same amount of cash because the illiquid bonds sell at discounts. Net outflows from t_1 equal $sR_1 - I_1$, so the fund still has $c-(sR_1 - I_1)$ cash remaining and must reach its target cash reserve $R_1 \cdot c$. Solving for assets A yields,

$$A = \frac{1}{1-\lambda}\left(c(R_1 - 1) + sR_1 - I_1\right) \tag{2}$$

Intuitively, the amount of assets A to be sold for cash includes: 1) c percent of the net return and 2) the amount of cash already depleted at t_1. The illiquidity of underlying assets λ creates an amplifier effect, where a fund must sell more assets if those assets are illiquid. The fund sells assets A but only receives $A(1-\lambda)$ in cash. Therefore, the fund suffers a loss equal to

$$A\lambda = \frac{\lambda}{1-\lambda}\left(c(R_1 - 1) + sR_1 - I_1\right) \tag{3}$$

For simplicity, I assume that at t_2, the fund experiences 0 inflows and outflows and gross return of 1. At t_2, total AUM equals $R_1 - sR_1 + I_1 - A\lambda$ and total shares remain constant at $1 - s + \frac{I_1}{R_1}$.

Solve for NAV at t_2 using equation (3),

$$\begin{aligned} NAV_{t_2} &= \frac{R_1 - sR_1 + I_1 - A\lambda}{1 - s + \frac{I_1}{R_1}} = \frac{R_1 - sR_1 + I_1 - A\lambda}{\frac{R_1(1-s) + I_1}{R_1}} \\ &= R_1 - \frac{R_1 A\lambda}{R_1(1-s) + I_1} \\ &= R_1 - \left(\frac{\lambda}{1-\lambda}\right)\frac{R_1\left(c(R_1 - 1) + sR_1 - I_1\right)}{R_1 - sR_1 + I_1} \end{aligned} \tag{4}$$

The decrease in NAV from t_1 to t_2 equals,

$$NAV_{t_1} - NAV_{t_2} = R_1 - \left(R_1 - \left(\frac{\lambda}{1-\lambda} \right) \frac{R_1 \left(c(R_1 - 1) + sR_1 - I_1 \right)}{R_1 - sR_1 + I_1} \right)$$

$$L = \left(\frac{\lambda}{1-\lambda} \right) \frac{R_1 \left(c(R_1 - 1) + sR_1 - I_1 \right)}{R_1 - sR_1 + I_1} \qquad (5)$$

where L is defined as the effect of liquidation lag on the fund's NAV from t_1 to t_2. The right-hand side of the equation is strictly non-negative because the possibility of the fund going bankrupt is excluded ($0 \leq s < 1$), and cash fully satisfies net outflows since $c > sR_1 - I_1$. Intuitively, liquidation lag represents the illiquidity discounts and trading/portfolio rebalancing costs associated with redemptions that hit NAV because the fund *gradually* sells assets over time to replenish cash. These illiquidity discounts and trading costs are captured by λ; the more illiquid the fund's underlying assets, the stronger the downward pressure on NAV. Therefore, funds holding illiquid bonds should experience more intense liquidation lag than funds holding liquid bonds. As a check, note that when $\lambda = 0$, liquidation lag has an effect of 0 as expected; $NAV_{t_2} = NAV_{t_1}$ because assets are essentially exchanged for cash at a 1-to-1 ratio shown by (1).

At time t_1, the fund experiences net outflows that are less than or equal to cash holdings: $sR_1 - I_1 \leq c$. However, it is optimal for the fund to sell assets A in t_2 rather than sell A in t_1. In the case of the latter, the fund would incur a worse impact on NAV since assets A would be sold at fire-sale prices $\delta\lambda$, where $\delta \geq 1$ (modeled below). In other words, gradual liquidation allows bond funds to avoid costly fire sales where assets are sold at a loss, grants more time for funds to seek better pricing/more agreeable buyers, and provides an opportunity to use future inflows to organically replenish cash reserves. Therefore, it is a weakly-dominated strategy for a fund to immediately fire-sale assets just to replenish cash holdings; selling assets in the future reduces downward NAV pressure. Because the fund is worse off by fire-selling to meet redemptions (shown further below), the fund chooses to use cash reserves. However, at time t_2, the fund must increase its cash balance back to percentage c. While true that this model is a static two-period model, and thus it may be NAV-maximizing for a fund to allow its cash balance to remain depleted at t_2, the model is structured to highlight economic intuition for the run mechanism. A dynamic infinite-horizon model, where cash c can be solved endogenously and vary over time, would better serve equilibrium calculations. However, there still remains a valid argument for requiring a fund to meet cash threshold c along the infinite-horizon, since a depleted cash reserve exacerbates future fire sales and creates worse front-running incentives.

Taking the partial derivative of liquidation lag L with respect to λ in (5) provides insights into the growth rate of L with respect to λ. Underlying illiquidity λ generates an amplifier effect on the magnitude of liquidation lag:

$$\frac{\partial L}{\partial \lambda} = \frac{1}{(1-\lambda)^2} \frac{R_1\left(c(R_1-1)+sR_1-I_1\right)}{R_1-sR_1+I_1} \tag{6}$$

The right-hand side is again non-negative, so that liquidation lag is not only increasing in illiquidity λ but also experiences an exponential growth effect. Equations (5) and (6) highlight the sensitivity of a fund's NAV to the illiquidity of underlying assets and lead to Hypothesis 3 described in the next section. After finding an appropriate measure for λ, holding constant net outflows, funds with highly illiquid assets in period t_1 should exhibit a significantly greater negative impact on NAV in next period t_2 than funds holding liquid assets.

Next, consider scenario 2 in which $sR_1 - I_1 = c + f$. The fund experiences net outflows at time t_1 that require the fund to a) use its entire cash/treasury balance and b) liquidate assets through fire sales in order to meet redemption demands. As in scenario 1, investors redeeming at t_1 receive $NAV_{t_1} = R_1$. Analogous to (1) above, the fund must replenish its cash buffer at time t_2

by selling bonds. Because the fund experiences net outflows exceeding cash, the fund has 0 remaining cash and must replenish its entirety.

$$R_1 \cdot c = A(1-\lambda)$$
$$A = \frac{R_1 \cdot c}{(1-\lambda)} \tag{7}$$

NAV at time t_2 is calculated by dividing total AUM by total shares. Again, for simplicity, assume inflows and outflows equal 0 at t_2 and gross return is 1.

$$NAV_{t_2} = \frac{R_1 - c - f(1+\delta\lambda) - A\lambda}{1 - s + \frac{I_1}{R_1}} \tag{8}$$

where δ represents the multiplier of downward price-pressure from fire sales, such that $\delta \geq 1$. The fund sells *A* assets in return for $A(1-\lambda)$ in cash for a net loss equal to $-A\lambda$, where again $0 \leq \lambda < 1$ and λ represents the illiquidity of underlying assets. Plugging (7) into (8) and solving for the NAV decline from t_1 to t_2 results in

$$NAV_{t_1} - NAV_{t_2} = R_1 - \frac{R_1 - c - f(1+\delta\lambda) - \left(\frac{\lambda R_1 \cdot c}{1-\lambda}\right)}{\frac{R_1 - sR_1 + I_1}{R_1}}$$
$$= R_1 - \frac{R_1 - (sR_1 - I_1)}{\frac{R_1 - sR_1 + I_1}{R_1}} + \frac{f(1+\delta\lambda) + \left(\frac{\lambda R_1 \cdot c}{1-\lambda}\right)}{\frac{R_1 - sR_1 + I_1}{R_1}}$$
$$L = \frac{\left(\frac{\lambda R_1^{2} \cdot c}{1-\lambda}\right) + R_1 f(1+\delta\lambda)}{R_1 - sR_1 + I_1} \tag{9}$$

The effect of liquidation lag when net outflows exceed cash and lead to fire sales, modeled by (9), is always greater than or equal to the effect of liquidation lag when cash is sufficient, modeled by (5). A proof is given in the Appendix. Intuitively, when net outflows lead to fire sales, the fund must not only a) instantaneously sell assets at harmful fire sale prices but also b) sell enough assets to replenish its *entire* cash reserve, resulting in more severe liquidation lag. The key idea is that funds that run out of cash become vulnerable to *any* amount of outflows, and therefore must replenish its cash reserves faster than funds sitting on a pile of cash. The increased pace at which the fund must gradually sell assets produces a larger run incentive. The variable δ partially captures this additional NAV impact, in addition to general fire-sale losses.

Taking the partial derivative of liquidation lag L with respect to illiquidity λ yields:

$$\frac{\partial L}{\partial \lambda} = \frac{\dfrac{R_1^{\,2} c}{(1-\lambda)^2} + R_1 f \delta}{R_1 - sR_1 + I_1} \tag{10}$$

Similar to the above, it is necessarily true that the sensitivity of liquidation lag L to illiquidity λ is at least as great for funds in scenario 2 versus funds in scenario 1. The proof follows from identical reasoning as in that in the Appendix. These results lead to Hypothesis 4 in Chapter 3.3. Bond funds that experience net outflows exceeding their cash buffer should experience a greater negative impact, increasing in λ, on future NAV than bond funds that are well capitalized with substantial cash and treasury holdings.

3.3 Hypotheses

The background and theory lead to the following hypotheses. Hypotheses 1-2 test for run-like behavior in corporate bond funds[2]. Then, Hypotheses 3-4 test for the underlying run incentives.

Hypothesis 1

Illiquid corporate bond funds exhibit greater sensitivity of flows to performance than liquid bond funds. In other words, given negative prior performance, illiquid bond funds experience more outflows than liquid funds.

Hypothesis 1 predicts stronger run behavior in illiquid bond funds than that in liquid funds, given poor prior performance. Although a fund's past returns are an important determinant of flows, the illiquidity of a fund's underlying assets should affect the degree to which a fund experiences run outcomes (as modeled in Chapter 3.2). Holding performance constant, redemption costs should impose a larger negative externality on investors in illiquid bond funds than investors in liquid funds, due to higher liquidation lag associated with trading illiquid assets and rebalancing the portfolio. Therefore, an investor in an illiquid fund believes he has more to lose if he remains in the fund than an investor in a liquid fund because costs from redemptions will have a greater negative impact on his returns. Illiquid funds should therefore experience greater outflows, and thus greater extent of run behavior than liquid funds. If there is enough instability in the market, redemption pressures may lead to self-driven runs for fear of being the last one out.

[2] Hypotheses 1-2 and their corresponding methods arise from Chen, Goldstein, and Jiang (2010), who found evidence of runs and run incentives in equity funds.

Hypothesis 2

The effect in Hypothesis 1 is greater in corporate bond funds held primarily by institutional investors than in bond funds held by retail investors. In other words, institutional funds are more sensitive to the effect of illiquidity on flows than retail funds.

Because institutional funds have a more sophisticated investor base compared to that of retail funds, institutional investors should be significantly more sensitive and responsive to market information, which may prompt more outflows given poor performance. Ben-David, Franzoni, and Moussawi (2012) find that during the financial crisis, hedge funds (held by mostly institutional investors) had much larger flow-performance sensitivity than mutual funds (held by mostly retail investors). Given poor returns, hedge fund investors withdrew capital three times more intensely than mutual fund investors. They attribute the institutional investor base of hedge funds to be an important factor in explaining why, given poor returns, hedge funds experience greater redemptions and liquidations than mutual funds. This clientele effect may occur because institutional investors have incentives in place that promote quick reaction to capital markets information: salaries tied to performance, advanced internal risk management systems, more capital to invest, greater variety of strategies, or just better skill in assessing investments. Other research has shown that investor sophistication does indeed speed up investors' reaction to information (Calvet, Campbell, and Sodini, 2009). Therefore, a similar clientele effect may drive institutional bond funds to experience more intense runs than retail bond funds. Institutional investors react faster to news that a fund is underperforming and so may redeem significantly more shares than retail investors.

Hypothesis 3

The illiquidity level of a bond fund's underlying assets is a significant predictor of future NAV growth, such that holding net outflows constant, the more illiquid the fund's underlying assets the greater the decrease in future NAV.

Because bond funds only gradually sell assets post-redemption, liquidation lag should lead to declines in future NAV as redemption costs are gradually reflected when bonds are sold to replenish cash. Therefore, holding outflows constant, an illiquid fund should experience a greater decrease in future NAV than a liquid fund because the illiquid fund is likely to sell assets at greater illiquidity discounts. This hypothesis follows directly from the theoretical model in equation (5). Consider a simple comparison between a real estate fund *R* that holds residential real estate assets and a treasury fund *T* that holds treasury notes. Given the funds are of identical size and experience identical outflows, it follows intuitively that *R* experiences a greater decrease in NAV than *T*, because *R*'s real estate assets suffer from greater illiquidity discounts and trading costs. The same relationship should exist among corporate bond funds, such that liquidation lag is more severe for funds holding illiquid bonds than funds holding liquid bonds.

Hypothesis 4

The effect in Hypothesis 3 is partially weakened by a large cash supply that prevents fire sales and diminishes liquidation lag. In other words, given large outflows, the future NAV of a fund with insufficient cash to meet redemptions is more sensitive to outflows and illiquidity than that of a fund with sufficient cash. Funds with insufficient cash should exhibit a greater NAV impact.

Hypothesis 4 follows from equation (8) in the theoretical model presented in Chapter 3.2. Funds that are insufficiently capitalized with cash and treasury securities are more likely to experience outflows greater than their cash reserves and therefore suffer from a) fire sales and b) more severe liquidation lag. Because the redemption demands fully deplete cash, the fund should experience more severe liquidation lag because it must sell assets faster to fully replenish its cash. Consequently, the downward pressure on NAV should be greater for funds with insufficient cash, creating a stronger incentive for investors to run. For example, consider two funds *A* and *B* that hold identical bonds; however, *A* has 5% cash while *B* has 20% cash. Given 3% outflows, both *A* and *B* satisfy redemptions through cash alone and experience similar effects of liquidation lag. But in a scenario with 7% outflows, *A* experiences 5% liquidation lag and 2% fire sales, compared to *B*'s 7% liquidation lag (visually depicted in Figure A in Chapter 3.2). Note two key differences. First, *A*'s *entire* cash balance is depleted and so experiences a "faster" liquidation lag than *B* because *A* needs to replenish cash *immediately* to avoid further fire sales, whereas *B* still has a comfortable 13% cash cushion. Second, *A*'s fire sales naturally generate a greater future NAV impact due to heavily discounted prices. Therefore, the future NAV for funds that do not have a sufficient cash buffer should be more sensitive to illiquidity and outflows.

4 Data

This section describes data sources, sample, key variables, and summary statistics.

4.1 Data Sources and Sample

Data come from three primary sources: CRSP Mutual Fund Database, Morningstar Mutual Fund Holdings, and TRACE Corporate Bond. CRSP (Center for Research in Security Prices) provides monthly fund-level summary data, such as total net assets and monthly returns for each fund *i* at month *t*. Morningstar Mutual Fund Holdings provides more granular holdings-level data, specifically the security name and market value for every underlying bond/security *j* that fund *i* holds at month *t*. The Morningstar dataset contains about 24 million observations of funds' underlying assets from 2004-2012. Finally, TRACE (Trade Reporting and Compliance Engine) provides transaction-level data such as the dollar amount and price for every secondary market corporate bond transaction. The TRACE dataset includes 71 million observations of corporate bond trades from 2004-2012. In this paper, the "fund-level" refers to aggregated fund summary data, the "holdings-level" refers to funds' individual security holdings data, and "transaction-level" refers to corporate bond trading data.

First, CRSP and Morningstar datasets are merged to determine the exact set of funds that make it into the sample. Merging occurs with CUSIP as the main axis. A CUSIP is a unique 8-9 digit alphanumeric code that uniquely identifies a security, and in the context of this paper, CUSIP uniquely identifies mutual funds as well as bonds. Because open-end mutual funds in both datasets contain a unique CUSIP identifier, funds that have their CUSIP in both the CRSP and Morningstar databases make it into the sample. Merging on CUSIP across CRSP and Morningstar allows for access to fund-level data from CRSP and holdings-level data from

Morningstar. The final dataset contains 879 U.S. open-end corporate bond mutual funds from January 2004 to June 2014.

Transaction-level data are derived from TRACE, a public database that provides information on all secondary market corporate bond trades after 2002 and represents all registered OTC transactions. TRACE data are eventually used to make detailed liquidity measurements for each fund's underlying bonds, based on their monthly trading history (details described below). The specific merge processes across the fund-level, holdings-level, and transaction-level are described in detail below.

4.2 Key Variables

4.2.1 Net Flows

Net flows are calculated using CRSP Mutual Fund monthly returns data, which provide each fund's total net assets and returns for each month. Bond fund *i* at month *t* has net flow calculated as:

$$Flow_{i,t} = \frac{TNA_{i,t} - TNA_{i,t-1}(1 + Return_{i,t})}{TNA_{i,t-1}}$$

where $TNA_{i,t}$ is total net assets for fund *i* in month *t*, and $Return_{i,t}$ is the monthly return for fund *i* in month *t*. $Flow_{i,t}$ represents the percentage change in a fund's total net assets excluding flow attributed to returns, as standard in literature (Chen, Goldstein, and Jiang, 2010; Coval and Stafford, 2007; Chen, Hanson, Hong, and Stein, 2008).

4.2.2 Prior Performance

A fund should have strong prior performance if it generates positive returns relative to its peer group average, as standard in capital markets theory. Investors prefer investing in bond funds that outperform the category average, and returns below that average are interpreted as underperforming, even if positive. For example, a fund that generates 10% underperforms if its peers generate an average of 15%. The idea of relative performance, that mutual fund returns are measured relative to peers, is widely accepted (Rajan, 2005; Morris and Shin, 2014).

This concept is applied when calculating return variables to proxy for prior performance. An investor wishing to invest in a high-yield bond fund would mostly likely compare the returns of that fund to the returns of other high-yield funds, using the category average return as the benchmark. Similar to Chen, Goldstein, and Jiang (2010), this paper measures a fund's excess category return, where a category *l* refers to a fund's Lipper Objective Code, given by CRSP. Excess category returns are calculated at 6, 3, 2, and 1-month moving averages in order to vary how far back investors look when measuring a fund's prior performance. $RetExCat_m$ represents a fund *i'*s excess return relative to the *m*-month moving average category return. Formally,

$$RetExCat_{i,l,m,t} = Return_{i,l,t-1} - MovingAverage_{l,m,t-1}$$

where $Return_{i,l,t-1}$ is fund *i*'s return at month *t-1* with Lipper category *l*, and $MovingAverage_{l,m,t-1}$ is the *m*-month moving average return of all funds with Lipper category *l* for month *t-1*. Therefore, $RetExCat_{i,l,m,t}$ is a lagged return variable that captures abnormal returns in excess of peer-group returns for the month prior.

4.2.3 Fund-Level Liquidity

For Hypotheses 1-2, liquidity is the main variable of interest and is determined by using Lipper Objective Codes that are provided by the CRSP Mutual Fund database, similar to the method in Chen, Goldstein, and Jiang (2010). Lipper Objective Codes classify funds by their intended investment styles, based on details described in each fund's prospectus, hence "fund-level liquidity" because a fund's specific holdings are not considered. Only corporate bond funds are included in the dataset and are further categorized as illiquid or liquid. The funds with the following Lipper Codes are categorized as liquid: A (A-rated), BBB (BBB-rated), FLX (Flexible Income), FX (Flexible Portfolio), I (Income), and SII (Short-Intermediate Investment Grade). Next, funds with the following Lipper Codes are categorized as illiquid: GB (General Bond), HY (High-Yield), IID (Intermediate-Investment Grade), LP (Loan Participation), MSI (Multi-Sector), and SFI (Specialty Fixed-Income). FLX and FX funds contain a small portion of stocks and money market securities and are categorized as liquid. GB funds do not have restrictions on bond quality or maturity and are categorized as illiquid. LP funds invest in bank loans, which are categorized as illiquid. Similarly, MSI funds invest a significant portion in high-yield bonds, and SFI funds use specialized trading strategies, including taking short positions and using leverage. For the purposes of this paper, the term “bond fund” refers to a corporate bond fund with one of the Lipper Objective Codes above.

In summary, the dataset contains 68,309 unique fund-share observations with 19,484 liquid fund observations and 48,825 illiquid fund observations, based on categories above. When comparing illiquid funds to liquid funds, illiquid funds are larger in terms of assets under management (mean $1,087mn compared to $682mn, and median $163mn compared to $135mn). Illiquid funds are also younger (mean 12.1 years compared to 15.6 years and median 10.4 years compared to 12.92 years) and generate slightly greater monthly returns (mean 0.47% compared to 0.36% and median 0.60% compared to 0.42%). Illiquid bond funds also charge slightly higher expenses (mean 0.86% compared to 0.84% and median 0.85% compared to 0.79%).

4.2.4 Holdings-Level Liquidity

A limitation to categorizing liquidity based on Lipper Codes is the lack of variation of liquidity within and across fund types. Because each fund is categorized as illiquid or liquid (a binary indicator), the model assumes all funds categorized as illiquid have underlying assets that are equally illiquid. Therefore, in Hypotheses 3-4, liquidity is measured in detail at the holdings-level based on each fund's specific underlying bonds. In other words, I carefully calculate a liquidity measurement for each security *j* that fund *i* holds at month *t*. These liquidity proxies are described in detail below.

a. Inter-quartile Price Range (IQR)

The Inter-quartile Price Range is a high frequency liquidity proxy used to measure a security's bid-ask spread, as used in Han and Zhou (2008), Pu (2009), and Schestag, Schuster, and Homburg (2014). The IQR takes the average of the difference between a bond's intraday trading price *P* at the 75th percentile and trading price at the 25th percentile, for each day *d*. The IQR makes a reasonable assumption that the bid price centers around the 25th percentile while the ask price centers around the 75th percentile, making the measurement less prone to outliers.

$$IQR_d = \frac{P_d^{75th} - P_d^{25th}}{P_d^{mean}}$$

As standard in the literature, I use the TRACE database to access bond trading data and measure a liquidity proxy for each bond. TRACE provides the following key data for every secondary market trade: CUSIP identifier, date, and price. As long as a bond has at least 3 trades in a given day, its daily IQR is included in the dataset, calculated based on its intraday trading prices. Additionally, prices greater than 200% and less than 0% of $1 notional are dropped in order to remove outlier prices (assume prices can't be negative and won't be double par value). This excludes only about .05% of trading prices. What remains is a daily IQR measure for all corporate bonds that traded from 2002-2012. Next, I determine monthly liquidity for all bonds by calculating the mean IQR for each month, yielding the following variables: CUSIP, month/year, mean IQR.

Next, I merge the TRACE transaction-level dataset with the Morningstar Mutual Fund Holdings dataset, using CUSIP and month as the main axes. The bond holdings dataset now includes the new mean IQR liquidity proxy. I compute a weighted average IQR measure for each fund at every month using the IQR for each of the funds' underlying bonds (details of the weighted average liquidity calculation appear in Chapter 5.3). The final IQR assigned to each fund *i* at month *t* is calculated using a 3-month moving average in order to more accurately gauge a fund's true liquidity level. Once the weighted average liquidity $IQR_{i,t}$ is calculated from the Morningstar dataset, the result is merged with the CRSP dataset using the funds' CUSIP as the main axis.

b. Roll (1984)

Similar to IQR, the Roll measure is a high-frequency bid-ask spread proxy developed in Roll (1984) and used as a common proxy to measure bond liquidity (Friewald, Jankowitsch, and Subrahmanyam, 2012; Dick-Nielsen, Feldhütter, and Lando, 2012). In this study, the Roll measure is used as a robustness check to ensure IQR accurately measures holdings liquidity (see Appendix). Intuitively, the Roll measure interprets intraday trading prices for bonds as negatively correlated, due to the bid-ask "bounce" where prices shift back and forth between bid and ask prices. Therefore, the more negatively correlated the prices, the greater the bid-ask spread and thus the greater the Roll measure. Similar to IQR, the Roll measure expects illiquid bonds to have larger bid-ask spreads, which correspond to greater Roll measures. The Roll measure as used in Schestag, Schuster, and Homburg (2014) is calculated as follows:

$$Roll_d = \begin{cases} 2\sqrt{-Cov(r_i, r_{i-1})} & if\ Cov(r_i, r_{i-1}) < 0 \\ 0 & if\ Cov(r_i, r_{i-1}) \geq 0 \end{cases}$$

$$\text{where } r_i = \frac{P_i - P_{i-1}}{P_{i-1}} \text{ is the return of the } i^{\text{th}} \text{ trade on day } d$$

Using the identical approach to calculating IQR, I use the TRACE database to access every trade for each bond *j* to calculate a daily Roll measure based on its intraday trading prices, as long as the bond has at least 4 trades on that day. The treatment of outliers, monthly Roll calculation, and merge processes is identical to that of IQR described above.

c. Cash and Treasury

The Morningstar holdings dataset is further used to measure the percentage cash and treasury holdings for each fund *i* at month *t*, $Cash\_Treasury_{i,t}$. Cash and treasury securities are determined by using string functions on each holding's security name. The variable *Cash_Treasury* allows the empirical model in Hypothesis 4 to test for the impact of cash reserves on run incentives. Similar to IQR above, $Cash\_Treasury_{i,t}$ from the Morningstar dataset is merged with CRSP using the funds' CUSIP as the main axis.

Table 1. Summary Statistics

The following table provides a summary distribution and definitions of main variables throughout the paper, many of which are described in detail in Chapter 4. Data comes from a 3-part merge of CRSP Mutual Fund (2004-2014), Morningstar Mutual Fund Holdings (2004 - 2012), and TRACE Corporate Bond (2004-2012). Additional details on the weighted average calculation for holdings illiquidity can be found in Chapter 5.3.

			Percentiles				
Variable	Mean	Standard Deviation	5%	25%	50%	75%	95%
Flow	0.91	7.92	-6.39	-1.46	-0.10	1.64	10.81
Illiq	0.72	0.45	0.00	0.00	1.00	1.00	1.00
RetExCat6	0.00	1.72	-2.28	-0.65	0.04	0.67	2.10
RetExCat3	0.01	1.57	-2.02	-0.60	-0.03	0.61	1.93
RetExCat2	0.00	1.32	-1.69	-0.51	-0.01	0.52	1.70
RetExCat1	0.00	0.93	-0.98	-0.22	0.00	0.23	1.03
Inst	0.30	0.46	0.00	0.00	0.00	1.00	1.00
Retail	0.66	0.47	0.00	0.00	1.00	1.00	1.00
Size	5.00	2.06	1.61	3.78	5.05	6.34	8.29
Age	2.19	1.03	0.16	1.69	2.41	2.88	3.51
Expense	0.86	0.38	0.30	0.60	0.84	1.05	1.61
Δ*NAV*	0.09	1.66	-2.73	-0.59	0.20	0.86	2.57
Cash_Treasury	0.09	0.12	0.00	0.00	0.05	0.15	0.33
Buffer	0.09	0.29	0.00	0.00	0.00	0.00	1.00
Illiq_hold_5	0.05	1.25	-0.86	-0.62	-0.34	0.14	2.52
Illiq_hold_7.5	0.05	1.26	-0.84	-0.63	-0.35	0.14	2.61
Illiq_hold_10	0.05	1.23	-0.82	-0.63	-0.37	0.15	2.59

Variable	Unit	Definition
Flow	%	Net flows
Illiq	Indicator	1 if fund is categorized as illiquid and 0 if liquid, based on Lipper Code
RetExCat#	%	Fund's % return in excess of the fund's category return, based on a 6, 3, 2, and 1-month moving averages
Inst	Indicator	1 if fund is primarily held by institutional investors and 0 otherwise
Retail	Indicator	1 if fund is primarily held by retail investors and 0 otherwise
Size	log($million)	Fund's total net assets, in log million
Age	log(years)	Fund's age relative to its inception date, in log years
Expense	%	Fund's expense ratio as a % of total net assets
Δ*NAV*	%	Fund's % change in NAV between months *t* and *t-1*
Cash_Treasury	%	Fund's % cash and treasury holdings
Buffer	Indicator	1 if net outflows > *Cash_Treasury* , 0 otherwise
Illiq_hold_#	St. deviations	Fund's illiquidity calculated using weighted IQR, based on Top 5, 7.5, and 10% most liquid holdings, and normalized

5 Methodology and Empirical Results

This section describes methodology for testing hypotheses in Chapter 3.3 and analyzes results.

5.1 Hypothesis 1

Illiquid funds should demonstrate greater sensitivity to past performance than liquid funds. In other words, given negative prior performance, bond funds that hold primarily illiquid assets should experience greater outflows than funds holding highly liquid assets. Therefore, illiquid funds should exhibit more run-like behavior. It is difficult to directly test for run incentives because of an endogeneity problem. Investor redemptions may occur for separate reasons: 1) run incentives, which this paper aims to identify or 2) belief that the fund is investing in underperforming assets. Therefore, large redemptions do not necessarily show evidence of runs because investors could just be moving assets out of poorly performing funds. Therefore, similar to the method used in Chen, Goldstein, and Jiang (2010), the following multivariate regression model isolates redemptions characteristic of run behavior from those driven by fundamentals. Formally,

$$Flow_{i,t} = B_0 Perf_{i,t-1} + B_1 Illiq_i \cdot Perf_{i,t-1} + B_2 Illiq_i + B_3 Control_{i,t} + B_4 Control_{i,t} \cdot Perf_{i,t-1} + \varepsilon_{i,t} \quad (11)$$

where $Flow_{i,t}$ is the net flow percentage of fund i during month t, $Perf_{i,t-1}$ is the past performance of fund i during month $t-1$, and $Illiq_{i,t}$ is an indicator variable, 1 if categorized as illiquid and 0 if categorized as liquid (see Chapter 4.2). The main variable of interest is the interaction term *Illiq*Perf*, which serves to measure a fund's flow-performance sensitivity, formally defined as $\frac{\partial Flow_{i,t}}{\partial Perf_{i,t-1}}$. Therefore, run behavior is measured by the decrease in net flows per unit decrease in past performance, in other words, how sensitive outflows are to negative performance. Excluding the effect of control variables, a liquid fund exhibits flow-performance sensitivity equal to B_0,

and an illiquid fund exhibits flow-performance sensitivity equal to $B_0 + B_1$.

To prevent outliers in $Flow_{i,t}$ from impacting results (for example funds opening, closing, or merging), *Flow* is winsorized at the 1 and 99th percentiles, as done in Chernenko and Sunderam (2013). As described in Chapter 4.2.2, past performance $Perf_{i,t-1}$ is measured using the excess category return variable $RetExCat_{i,l,m,t}$, where *l* is a fund's Lipper code and category. Four excess category return variables are calculated using the moving average at 1, 2, 3, and 6-month intervals: $RetExCat_{i,l,6,t}$, $RetExCat_{i,l,3,t}$, $RetExCat_{i,l,2,t}$, and $RetExCat_{i,l,1,t}$. These variables are referred to as *RetExCat6*, *3*, *2*, and *1* and serve to gauge how far historically investors look when measuring past performance. If the coefficient of *Illiq*Perf* is positive and significant then, holding past performance constant, a fund's liquidity level significantly impacts the magnitude of future flows. Results are reported in Table 2.

The interaction term *Illiq*Perf* is positive and significant at the 1 percent level for all proxies of prior performance. Funds categorized as illiquid exhibit a 0.156% additional decrease in net flows per 1% decrease in excess category return *RetExCat6*. Therefore, illiquid bond funds experience 21.7% (0.874 vs. 0.718) more outflows than liquid funds, given a 1% decrease in returns. A similar interpretation applies when using *RetExCat3*, *2*, and *1* as proxies for past performance; the interaction term *Illiq*Perf* is significant at the 1% percent level and corresponds to illiquid bond funds having 22.3% (0.825 vs. 0.641), 40.1% (0.832 vs. 0.594), and 43.6% (0.838 vs. 0.584) more outflows than liquid funds, associated with a 1% decrease in returns, respectively. These findings are in line with the empirical results shown in Chen, Goldstein, and Jiang (2010). After categorizing equity mutual funds as either liquid or illiquid

Table 2. Effect of Illiquidity on Flow-Performance Sensitivity: Overall Sample
The dependent variable is the net flow for each fund in month *t*. Observations are at the fund-month level. The main variables of interest are *Perf* and *Illiq*Perf*, as per the model in (11), and gives insight into the effect of illiquidity on funds' flows for a given measure of past performance. The past performance proxies are RetExCat6, 3, 2, and 1, with the numbers denoting the number of months in the moving average when calculating excess category return (see Chapter 4). Each column is a regression of the model in (11) but with a different proxy for past performance *Perf*. *Illiq* is an indicator variable with a value of 1 if the fund is categorized as illiquid and 0 if liquid, based on Lipper Codes in the CRSP database (details in Chapter 4). *Flow* is winsorized at the 1 and 99th percentiles.
* p<0.1; ** p<0.05; *** p<0.01

Independent Variables	(1) RetExCat6 $Flow_t$	(2) RetExCat3 $Flow_t$	(3) RetExCat2 $Flow_t$	(4) RetExCat1 $Flow_t$
$Perf_{t-1}$	0.718***	0.641***	0.594***	0.584***
	(8.52)	(7.03)	(5.59)	(3.97)
$Illiq*Perf_{t-1}$	0.156***	0.184***	0.238***	0.254***
	(4.08)	(4.51)	(5.09)	(4.01)
<u>Controls</u>				
Illiq	-0.117**	-0.118**	-0.118**	-0.118**
	(2.00)	(2.03)	(2.03)	(2.01)
$Inst*Perf_{t-1}$	-0.279***	-0.267***	-0.315***	-0.483***
	(6.82)	(5.96)	(5.88)	(5.96)
$Size*Perf_{t-1}$	-0.009	-0.017*	-0.014	0.003
	(0.94)	(1.70)	(1.22)	(0.21)
$Age*Perf_{t-1}$	-0.100***	-0.076***	-0.077***	-0.112***
	(5.27)	(3.59)	(3.07)	(3.11)
$Expense*Perf_{t-1}$	-0.266***	-0.257***	-0.202***	-0.135*
	(5.58)	(5.00)	(3.38)	(1.69)
Inst	-0.651***	-0.650***	-0.649***	-0.646***
	(10.14)	(10.11)	(10.10)	(10.04)
Size	0.243***	0.243***	0.242***	0.241***
	(15.96)	(15.96)	(15.90)	(15.85)
Age	-1.859***	-1.858***	-1.857***	-1.857***
	(55.59)	(55.50)	(55.47)	(55.43)
Expense	-0.130	-0.132	-0.130	-0.129
	(1.59)	(1.61)	(1.58)	(1.57)
Constant	4.003***	4.000***	4.001***	4.004***
	(28.26)	(28.21)	(28.22)	(28.22)
R^2	0.05	0.05	0.05	0.05
Observations	68,309	68,309	68,309	68,309

using CRSP style codes, they find a coefficient for *Perf* of 0.77 (t-stat = 16.1) and a coefficient for *Illiq*Perf* of 0.11 (t-stat = 1.94) when using *RetExCat6* as their proxy for prior performance.

Additionally, institutional funds are less performance-chasing than retail funds, as the interaction term *Inst*Perf* is negative and significant at the 1% level across all prior performance proxies. CRSP provides an indicator variable *Inst* that takes on a value of 1 if a fund is primarily held by institutional investors. A separate indicator variable *Retail* takes on a value of 1 if a fund is primarily held by retail investors. The interaction term *Inst*Perf* shows that institutional bond funds are less sensitive to performance than non-institutional (retail) funds. Given a 1% decrease in prior performance, institutional funds experience significantly less outflows than retail funds, evidence that institutional investors are less performance-chasing than retail investors. This result parallels the result in Hypothesis 2 below.

The empirical model in (11) and corresponding results provide sufficient statistical evidence to confirm Hypothesis 1 conclusive. The positive and significant coefficients for *Illiq*Perf* highlight the impact of illiquidity on run behavior in bond funds. These results show that, during an economic downturn, illiquid funds are more likely to be vulnerable to large outflows that may spark a dramatic run. The real possibility of abnormal flows amplifying into runs, based on the recent QE taper tantrum, highlights the increasingly important role of asset managers in maintaining financial stability (Feroli, et. al, 2014).

5.2 Hypothesis 2

In Hypothesis 2, the phenomenon identified in Hypothesis 1 is expected to be more severe for bond funds held by institutional investors than for those held by retail investors. Intuitively, the average institutional investor is likely more sophisticated than the average retail investor, since institutional investors have access to better technology for due diligence, performance incentives, and skill in quickly trading on new market information. In contrast to many retail investors who adopt a passive approach, institutional investors actively react to market changes that trigger trades, inflows, and outflows. Therefore, institutional investors may have a better ability to measure a bond fund’s underlying liquidity than retail investors. During an economic downturn, institutional funds are therefore expected to exhibit more intense run behavior. The latest U.S. financial crisis has shown this to be the case, as mostly large

Table 3. Effect of Illiquidity on Flow-Performance Sensitivity: Sub-Sample of Institutional Funds
The dependent variable is the net flow for each fund in month *t*. Observations are therefore at the fund-month level. An institutional fund is primarily held by institutional investors. Only institutional funds make it into this sample. An indicator variable in the CRSP Mutual Fund dataset identifies such funds. Again, the main variables of interest are *Perf* and *Illiq*Perf*, as per the model in (11), which examines the effect of illiquidity on funds' flows for a given measure of past performance. The past performance proxies are RetExCat6, 3, 2, and 1, with the numbers denoting the number of months in the moving average when calculating excess category return (see Chapter 4). Each column is a regression of the model in (11) but with a different proxy for past performance *Perf*. *Illiq* is an indicator variable with a value of 1 if the fund is categorized as illiquid and 0 if categorized as liquid (details in Chapter 4). *Flow* is winsorized at the 1 and 99th percentiles.

* $p<0.1$; ** $p<0.05$; *** $p<0.01$

Independent Variables	(1) RetExCat6 $Flow_t$	(2) RetExCat3 $Flow_t$	(3) RetExCat2 $Flow_t$	(4) RetExCat1 $Flow_t$
$Perf_{t-1}$	0.219	0.314*	0.195	0.394
	(1.38)	(1.85)	(1.00)	(1.42)
$Illiq*Perf_{t-1}$	0.255***	0.278***	0.327***	0.318**
	(3.68)	(3.78)	(3.86)	(2.58)
Controls				
Illiq	-0.225**	-0.228**	-0.231**	-0.228**
	(2.09)	(2.11)	(2.14)	(2.11)
$Size*Perf_{t-1}$	-0.054***	-0.075***	-0.080***	-0.097***
	(2.88)	(3.69)	(3.35)	(2.78)
$Age*Perf_{t-1}$	0.012	0.038	0.093*	0.212***
	(0.29)	(0.83)	(1.73)	(2.80)
$Expense*Perf_{t-1}$	0.002	-0.129	-0.112	-0.718***
	(0.02)	(0.84)	(0.63)	(2.91)
Size	0.306***	0.308***	0.309***	0.310***
	(10.88)	(10.95)	(10.95)	(10.98)
Age	-1.821***	-1.820***	-1.821***	-1.818***
	(27.67)	(27.66)	(27.67)	(27.60)
Expense	0.243	0.242	0.239	0.210
	(1.21)	(1.20)	(1.19)	(1.05)
Constant	2.790***	2.780***	2.786***	2.785***
	(11.58)	(11.53)	(11.55)	(11.53)
R^2	0.04	0.04	0.04	0.04
Observations	20,786	20,786	20,786	20,786

institutional investors such as insurance firms, pension funds, and hedge funds, redeemed capital from mutual funds, MMMFs, prime brokerages, etc. dramatically faster than retail investors.

The same model in (11) is used to test Hypothesis 2, though the sample is divided into institutional and retail. Results appear in Table 3 and Table 4.

Table 4. Effect of Illiquidity on Flow-Performance Sensitivity: Sub-Sample of Retail Funds
The dependent variable is the net flow for each fund in month *t*. Observations are therefore at the fund-month level. A retail fund is primarily held by retail investors. Only retail funds make it into this sample. An indicator variable in the CRSP Mutual Fund dataset identifies such funds. Again, the main variables of interest are *Perf* and *Illiq*Perf*, as per the model in (11), which examines the effect of illiquidity on funds' flows for a given measure of past performance. The past performance proxies are RetExCat6, 3, 2, and 1, with the numbers denoting the number of months in the moving average when calculating excess category return (see Chapter 4). Each column is a regression of the model in (11) but with a different proxy for past performance *Perf*. *Illiq* is an indicator variable with a value of 1 if the fund is categorized as illiquid and 0 if categorized as liquid (details in Chapter 4). *Flow* is winsorized at the 1 and 99th percentiles.

* p<0.1; ** p<0.05; *** p<0.01

Independent Variables	(1) RetExCat6 $Flow_t$	(2) RetExCat3 $Flow_t$	(3) RetExCat2 $Flow_t$	(4) RetExCat1 $Flow_t$
$Perf_{t-1}$	0.885***	0.760***	0.738***	0.657***
	(9.34)	(7.38)	(6.12)	(3.98)
$Illiq*Perf_{t-1}$	0.092*	0.117**	0.169***	0.220***
	(1.93)	(2.29)	(2.89)	(2.89)
Controls				
Illiq	-0.056	-0.057	-0.056	-0.056
	(0.78)	(0.79)	(0.78)	(0.78)
$Size*Perf_{t-1}$	0.224***	0.224***	0.223***	0.223***
	(12.18)	(12.15)	(12.08)	(12.04)
$Age*Perf_{t-1}$	-1.888***	-1.885***	-1.883***	-1.884***
	(47.12)	(46.98)	(46.94)	(46.91)
$Expense*Perf_{t-1}$	-0.275***	-0.277***	-0.275***	-0.270***
	(2.95)	(2.97)	(2.95)	(2.89)
Size	0.018	0.013	0.019	0.049**
	(1.63)	(1.09)	(1.41)	(2.55)
Age	-0.172***	-0.147***	-0.167***	-0.240***
	(7.71)	(5.90)	(5.61)	(5.67)
Expense	-0.317***	-0.282***	-0.224***	-0.083
	(6.15)	(5.04)	(3.46)	(0.96)
Constant	4.271***	4.268***	4.268***	4.266***
	(26.05)	(25.99)	(25.99)	(25.96)
R^2	0.06	0.05	0.05	0.05
Observations	45,599	45,599	45,599	45,599

The institutional fund sub-sample yields coefficients for *Illiq*Perf* of 0.255, 0.278, 0.327, and 0.318 and are all significant at the 1% level when using *RetExCat6, 3, 2,* and *1* as proxies for prior performance, respectively. However, when looking at the retail fund sub-sample, for the same proxies for prior performance, coefficients for *Illiq*Perf* are dramatically lower: 0.092, 0.117, 0.169, and 0.220, evidence of less sensitivity to illiquidity for retail funds. A further comparison of the magnitudes of *Illiq*Perf* for institutional funds and retail funds shows that institutional funds exhibit a greater effect of illiquidity on flow-performance sensitivity and therefore more intense run behavior. Looking at *Perf* and *Illiq*Perf*, an illiquid institutional bond fund exhibits sensitivity of net flows to past performance that is 116% greater than that of a liquid institutional fund (0.474 vs. 0.219), when using *RetExCat6*. However, an illiquid retail bond fund has flow-performance sensitivity only 10% greater than that of a liquid retail fund (0.977 vs. 0.885). A similar analysis using *RetExCat3*, *2*, and *1* reveals 89% (0.592 vs. 0.314), 168% (0.522 vs. 0.195), and 81% (0.712 vs. 0.394) greater sensitivity of flows to performance, respectively, for illiquid institutional funds compared to that for liquid institutional funds. However, an illiquid retail fund exhibits a much weaker relationship: only 15% (0.877 vs. 0.760), 23% (0.907 vs. 0.738), and 33% (0.877 vs. 0.657) greater than that for liquid retail funds when using *RetExCat3*, *2*, and *1*, respectively.

Interestingly, in light of the results in Hypothesis 1, institutional bond funds are on average more sensitive to illiquidity but less sensitive to performance, compared to retail funds. In other words, institutional investors do not chase performance as much as retail investors but are instead more sensitive to the illiquidity level of the fund's holdings. Recall the interaction term *Inst*Perf* in Table 2. The coefficients for *Inst*Perf* are -0.279, -0.267, -0.315, and -0.483 for *RetExCat6*, *3*, *2*, and *1* respectively and statistically significant at the 1% level. Furthermore, a comparison of the coefficients for *Perf* in Tables 3 and 4 reveals greater coefficients for retail funds (0.885, 0.760, 0.738, and 0.657) than those for institutional funds (0.219, 0.314, 0.195, 0.394) for *RetExCat6*, *3*, *2*, and *1*, respectively. All else equal, institutional funds are *less sensitive to performance* than retail funds. However, institutional funds are *more sensitive to illiquidity* than retail funds. Using *RetExCat6* again and looking at Tables 3 and 4, given a decrease of 1% in prior performance, illiquid institutional bond funds experience 116% more outflows than liquid institutional funds, but illiquid retail funds only experience 10.4% more outflows than liquid retail funds.

This result may be explained by investor sophistication and performance incentives described in Chapter 3. Perhaps institutional funds can more accurately assess a fund's true performance, through historical track record or future forecasts, and therefore pay less attention to short-term fluctuations. Similarly, institutional funds may be better equipped with tools and knowledge than retail investors to measure liquidity levels of funds' underlying assets. If institutional investors have access to detailed fund holdings data and use advanced metrics to measure liquidity, they may be better prepared to avoid losses than retail investors who often invest based on relative performance and fund category. Ben-David, Franzoni, and Moussawi (2012) find this clientele effect to be a reasonable explanation, since institutional investors have structural incentives, such as performance-based bonuses, risk management systems, and complex strategies, motivating fast reaction to new market information. Evidence from past financial crises also shines light on institutional funds' greater sensitivity to illiquidity, since institutional investors, such as pension, insurance, and hedge funds, are often among the first to withdraw capital from failing banks and other investment vehicles in an economic collapse.

The results in Tables 3 and 4 above provide sufficient statistical evidence to conclude that both institutional and retail bond funds experience run behavior in the form of excess outflows driven by illiquidity. Furthermore, institutional bond funds are less sensitive to performance but more sensitive to illiquidity. In regards to regulation and policy, these results provide insight and strong support that institutional bond funds may be more susceptible to runs compared to retail funds in crises.

5.3 Hypotheses 3 and 4

While Hypotheses 1-2 examine run behavior in corporate bond funds, Hypotheses 3-4 look to identify the underlying run incentives that drive this behavior. Hypothesis 3 proposes that the illiquidity of a fund's underlying assets is a significant predictor of future NAV growth. In other words, the intensity of liquidation lag driving the NAV impact should be directly related to underlying illiquidity, as theorized in Chapter 3.2. Given outflows, funds investing in illiquid bonds should face greater declines in future NAV and therefore exhibit a greater run incentive than funds investing in liquid bonds- in agreement with equation (5). Furthermore, Hypothesis 4 argues that this relationship should be more dramatic for funds that do not hold enough cash to satisfy redemptions, prompting fire sales. Intuitively, funds that hold less cash are more vulnerable to fire sales, since low cash levels are often insufficient to meet large redemption requests. Therefore, as noted in Chapter 3.2, funds that do not hold a large enough cash buffer against redemptions experience more severe liquidation lag and should exhibit greater sensitivity of NAV to underlying holdings illiquidity.

To test Hypotheses 3 and 4, it is imperative to accurately measure the illiquidity of a fund's underlying bonds, a challenge that this paper overcomes. While Feroli, Kashyap, Shoenholtz, and Shin (2014) examine aggregate bond fund data for evidence of runs, this paper is the first to study run incentives in corporate bond funds by analyzing illiquidity using underlying bond holdings data. I present the detailed methodology in testing for Hypotheses 3-4 below, propose the empirical model, and analyze results.

I take the theory to the data by measuring illiquidity in a way that mirrors the run story in Chapter 3.2. A single liquidity proxy for each fund j at month t is calculated by taking the weighted average liquidity across only the fund's most liquid holdings. Corporate bond funds sell only their most liquid assets first, corresponding to previous research (Manconi, Massa, and Yasuda, 2012). Therefore, it is most appropriate to measure the liquidity of only the most liquid bonds in the fund, since these are the ones that are going to be sold post-redemption. The fund's liquidity level is measured by calculating three weighted average liquidity metrics: one for each of the Top 5%, 7.5%, and 10% most liquid holdings. These percentage levels are very close to the 10th, 5th, and 3rd percentiles of net flows in the CRSP dataset, respectively. A more intuitive explanation follows from Figure 5A.

Figure 5A: Taking Theory to the Data for Hypotheses 3 and 4

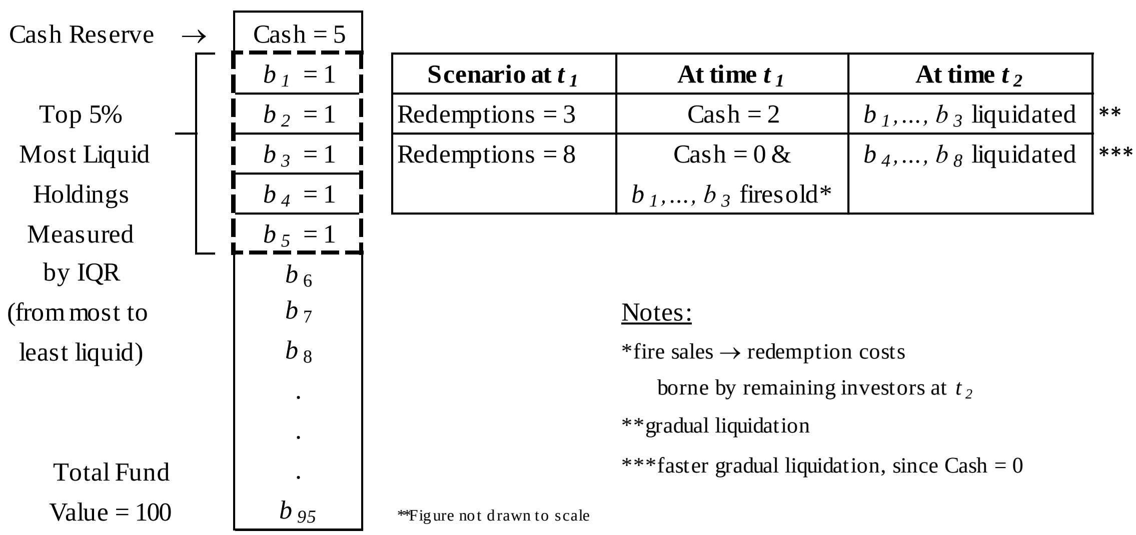


Figure 5A is adapted from Figure A in Chapter 3.2 but emphasizes the fund's Top 5% most liquid holdings. Bond b_1 is the most liquid (has the smallest IQR) and b_{95} is the least liquid (has the greatest IQR). Recall from Chapter 4, IQR is a bid-ask spread estimator, such that a larger bid-ask spread corresponds to a more illiquid asset. Using IQR as the liquidity proxy for the top 5% most liquid holdings, the weighted average liquidity of the fund, by market value, in this example equals $\sum_{n=1}^{5} \frac{IQR(b_n)}{5}$. Again, the intuition is that bonds $b_1,\dots,b_5$ are most likely to be sold post-redemption in order to replenish cash reserves. By calculating three weighted average liquidity metrics for the Top 5%, 7.5%, and 10% most liquid holdings, I can vary tests for liquidation lag, for ex. in the above scenario where redemptions = 8 and $b_4, \ldots, b_8$ are sold.

Additionally, it is important to note that weighted average liquidity is calculated *excluding* cash and treasury holdings. In the scenario with redemptions = 3, the fund has sufficient cash to satisfy redeeming investors. However, the fund still faces run incentives due to liquidation lag, because bonds $b_1, \ldots, b_3$ are still expected to be sold over the near short-term to replenish the cash target of 5. This is formally defined in equation (4) in Chapter 3.2. By excluding cash when calculating a fund's liquidity, the variable *Illiq_hold* accurately measures the impact of liquidation lag, because the bonds of interest are exactly those within the dotted bold lines in Figure 5A. This liquidity proxy guarantees that illiquid funds with a lot of cash are NOT immune to run incentives. Although large cash balances do prevent fire sales, these funds still experience liquidation lag because illiquid bonds are soon sold to replenish cash reserves.

I jointly test for Hypotheses 3-4 using the following time-series panel regression model,

$$\begin{aligned}\Delta NAV_{i,t} = {} & B_0 Flow_{i,t-1} + B_1 Flow_{i,t-1} \cdot Illiq\_hold_{i,t-1} + B_2 Flow_{i,t-1} \cdot Illiq\_hold_{i,t-1} \cdot Buffer_{i,t-1} + \\ & B_3 Flow_{i,t-1} \cdot Buffer_{i,t-1} + B_4 Buffer_{i,t-1} + B_5 Illiq\_hold_{i,t-1} + B_6 Illiq\_hold_{i,t-1} \cdot Buffer_{i,t-1} + \varepsilon_{i,t}\end{aligned} \qquad (12)$$

where $\Delta NAV_{i,t} = \frac{NAV_{i,t} - NAV_{i,t-1}}{NAV_{i,t-1}} \cdot 100$ i.e. percent NAV growth, and $Flow_{i,t-1}$ is the lagged percent net flow as used in (11). $Illiq\_hold_{i,t-1}$ is measured by the weighted average liquidity of a fund's Top 5%, 7.5%, or 10% most liquid holdings in the month prior, calculated using IQR as described above. $Illiq\_hold_{i,t-1}$ is then normalized and interpreted as the number of standard deviations from the mean. Finally, $Buffer_{i,t-1}$ is an indicator that equals 1 if $Flow_{i,t-1} < 0 \;\&\; (-1) \cdot Flow > Cash\_Treasury_{i,t-1}$, where $Cash\_Treasury_{i,t-1}$ is the percentage sum of cash and treasury holdings at month *t-1* (described in Chapter 4.2). In other words, the variable $Buffer_{i,t-1}$ equals 1 when net outflows exceed cash holdings, which allows the model to test the impact of fire sales and liquidation lag on NAV for funds that do not have enough cash to meet redemption demands. $\Delta NAV_{i,t}$ and $Illiq\_hold_{i,t-1}$ are winsorized at the 1 and 99th percentiles in order to mitigate the effect of outliers. $\Delta NAV_{i,t}$ and $Flow_{i,t-1}$ appear normally distributed, while $Illiq\_hold_{i,t-1}$ is log-normally distributed. Therefore, the optimal fitted log-normal distribution for $Illiq\_hold_{i,t-1}$ is used to normalize the variable to the number of standard deviations, so that an increase of 1 in $Illiq\_hold_{i,t-1}$ corresponds to a 1 standard deviation increase in holdings illiquidity. Normalization simplifies interpreting results from the model. Lastly, fund fixed-effects and time fixed-effects serve as additional controls.

Given net outflows, illiquid funds are expected to experience a greater negative impact on future NAV than liquid funds, because the effect of liquidation lag is increasing in the illiquidity of underlying bonds, represented by *Illiq_hold* (in the empirical model above) and λ (in the theoretical model). Therefore, key variables of interest correspond to coefficients $B_0,\ldots, B_3$ for the interaction terms with *Flow*. For testing Hypothesis 3, the interaction term *Flow*Illiq_hold* measures the effect of holdings illiquidity on NAV growth given net flows. The coefficient B_1 is expected to be positive and significant because holding more illiquid bonds should intensify liquidation lag. For testing Hypothesis 4, the interaction terms *Flow*Illiq_hold*Buffer* and *Flow*Buffer* highlight the effect of maintaining a sufficient cash buffer on future NAV. Liquidation lag should have a greater negative impact on future NAV if cash/treasury holdings are unable to meet redemption requirements. Holding outflows constant, an illiquid bond fund that also hits its cash/treasury buffer should experience fire sales that add downward pressure on a fund’s future NAV. Results appear in Table 5.

Table 5. Effect of Liquidation Lag and Cash/Treasury Buffer on NAV Growth: Overall Sample
The dependent variable is the change in NAV for each fund from time *t* to time *t-1* in 1-month intervals. Observations are therefore at the fund-month level. The sample includes all fund-months for corporate bond funds that are included in both the Morningstar Mutual Fund Holdings dataset and CRSP Mutual Fund dataset. Each of the three columns follows from the empirical model in (12) but calculates *Illiq_hold* using a weighted average liquidity, based on a bid-ask spread proxy (Interquartile Price Range) and on different thresholds of the most liquid holdings. This specific weighted average calculation is explained in Chapter 5.3 and models liquidation lag in the bond fund run story. *Illiq_hold* is winsorized at the 1 and 99th percentiles, normalized using a log-normal fit, and interpreted as the number of standard deviations from the mean. The main variables of interest are the interaction terms with *Flow*, the net flow percentage for each fund in month *t* identical to that in equation (11). *Buffer* is an indicator variable that takes on a value of 1 if net outflows exceed total cash and treasury holdings for that month and 0 otherwise. *Flow*, *Illiq_hold*, and *Buffer* are 1-month lagged variables. ΔNAV is winsorized at the 1 and 99th percentiles. Fund fixed-effects and time fixed-effects serve as controls.

* p<0.1; ** p<0.05; *** p<0.01

Independent Variables	(1) Top 5% ΔNAV_t	(2) Top 7.5% ΔNAV_t	(3) Top 10% ΔNAV_t
$Flow_{t-1}$	0.00167	0.00159	0.00173
	(1.49)	(1.42)	(1.55)
$Flow_{t-1}$*$Illiq\_hold_{t-1}$	0.00142**	0.00143**	0.00124**
	(2.37)	(2.47)	(2.05)
$Flow_{t-1}$*$Illiq\_hold_{t-1}$*$Buffer_{t-1}$	0.00605***	0.00603***	0.00581***
	(2.94)	(2.83)	(2.64)
$Flow_{t-1}$*$Buffer_{t-1}$	0.00982***	0.01001***	0.01004***
	(3.14)	(3.20)	(3.21)
Controls			
$Buffer_{t-1}$	-0.01916	-0.01744	-0.01588
	(0.81)	(0.74)	(0.67)
$Illiq\_hold_{t-1}$	0.00641	0.00808	0.01105
	(0.70)	(0.89)	(1.19)
$Illiq\_hold_{t-1}$*$Buffer_{t-1}$	0.05518***	0.04526***	0.04174**
	(3.56)	(2.89)	(2.51)
Constant	0.26510***	0.26427***	0.26415***
	(3.63)	(3.62)	(3.62)
R^2	0.55	0.55	0.55
Observations	31,770	31,770	31,770

The coefficients for the key interaction terms *Flow*Illiq_hold*, *Flow*Illiq_hold*Buffer*, and *Flow*Buffer* are all positive and significant at the 5%, 1%, and 1% levels, respectively for all illiquidity proxies. Illiquid bond funds exhibit a greater sensitivity of NAV growth to outflows, noted by the interaction term *Flow*Illiq_hold*. The magnitude of run incentives is indeed directly related to illiquidity; the more illiquid the fund, the bigger the expected decline in NAV, in agreement with the theory in Chapter 3.2. Furthermore, the model reveals statistically conclusive evidence that holding enough cash to prevent fire sales significantly impacts the intensity of run incentives. Recall that the indicator variable *Buffer* only takes a value of 1 if net outflows exceed cash and treasury holdings. The coefficients for *Flow*Illiq_hold*Buffer* are not only significant but also several times larger than those of *Flow*Illiq*, suggesting that funds lacking sufficient cash and treasuries present run incentives several times greater than those for funds with sufficient cash.

Applying the model to highly illiquid funds, those of most interest in this paper, one can calculate the magnitude of the NAV impact and thus identify the run incentive due to liquidation lag. The regression in column (2), measuring illiquidity with the Top 7.5% most liquid holdings, shows that funds with a sufficient cash buffer (*Buffer* = 0) and holding assets with illiquidity at 3 deviations (*Illiq_hold* = 3) experience a NAV impact of 5.9 basis points given a net outflow of 10%. However, funds with identical illiquidity at 3 deviations with insufficient cash reserves (*Buffer* = 1) experience a NAV impact of 34.0 basis points, about 5.8x that of funds with sufficient cash. The regressions in columns (1) and (3), using Top 5% and Top 10% most liquid holdings, yield almost identical magnitudes for funds with illiquidity at 3 deviations: 5.9 and 5.5 basis points when *Buffer* = 0 and 33.9 and 32.9 basis points when *Buffer* = 1, respectively. However, when considering funds that hold bonds of more extreme illiquidity, say 5 deviations (*Illiq_hold* = 5), one finds that the NAV impact increases to about 8.7 basis points with a sufficient cash buffer (*Buffer* = 0) and 48.9 basis points with an insufficient cash buffer (*Buffer* = 1), in the range of 42-48% greater run incentives than those in funds with *Illiq_hold* = 3.

Interestingly, as derived in the model in Chapter 3.2 and in Hypothesis 4, the interaction term *Flow*Buffer* reveals that even a liquid fund with mean *Illiq_hold* = 0, is not immune to run incentives if it lacks sufficient cash and treasury holdings. A comparison of the magnitudes of *Flow* and *Flow*Buffer* reveals that funds with *Illiq_hold* = 0 but with insufficient cash (*Buffer* =

1) experience about 6.8-7.3x greater sensitivity to outflows than funds with a sufficient cash (*Buffer* = 0). Given 10% net outflows and *Illiq_hold* = 0, a fund with insufficient cash has a NAV impact of about 10 basis points compared to only 1.6 basis points for a fund with sufficient cash. This relationship shows the economic importance of maintaining substantial cash reserves; a strong cash and treasury buffer significantly mitigates the intensity of run incentives.

There is sufficient statistical evidence to claim Hypotheses 3 and 4 conclusive. These findings show that the illiquidity level of a fund's holdings has important economic significance; funds that hold extremely illiquid bonds may suffer from greater liquidation lag and run incentives several times more severe than those in funds of average-liquidity. Lastly, a lack of cash and treasury holdings as a buffer against redemptions provides an additional channel that creates large downward pressure on NAV through fire sales and more severe liquidation lag.

For the purposes of a policymaker or regulator, these results confirm that run incentives are driven by two key significant factors: 1) illiquidity of a bond fund's underlying assets and 2) level of cash and treasury holdings. The combination of liquidation lag driven by illiquid holdings and the lack of a sufficient cash/treasury buffer may explain what drives large illiquid corporate bond funds to experience run behavior, identified above in Hypotheses 1-2. Furthermore, these results are useful in providing insight into the funds that are most likely to propagate runs during crises. As cited in Chapter 2, previous studies have shown that during the financial crisis and post-crisis, a low-interest rate environment presented opportunities for large asset managers to reach for yield. Corporate bond funds that reach for yield are often exactly the funds that hold risky high-yield bonds and little cash, since cash sitting in a vault earns minimal returns compared to the generous returns from investing in risky bonds. These funds may exactly represent the small percentage of funds with illiquid holdings at 3-5 deviations, analyzed in this paper, and therefore the funds that pose the greatest systemic risk. Thus, corporate bond funds that take excessive risks by investing in highly illiquid assets and reducing their cash balances may achieve above-average returns during good times but are vulnerable to damaging runs during bad times. Further research could shine light on effective policy that most effectively limits excess risk-taking by bond funds, diminishes the externality posed by liquidation lag, and ensures bond funds are well capitalized with enough cash to withstand large redemptions and minimize run incentives.

6 Conclusion

This paper reveals evidence of run behavior and identifies run incentives in U.S. open-end corporate bond funds. Run incentives arise from bond funds' open-end legal structure that leads to liquidation lag post-redemption. Because open-end funds allow investors to buy and sell shares at daily NAV, funds must bear redemption costs related to trading and portfolio balancing. These redemption costs only affect the funds' remaining investors and therefore generate strong negative externalities when funds gradually liquidate assets to replenish cash reserves. Therefore, during an economic shock or period of poor performance, bond funds experience dramatic redemptions characteristic of a run, as illiquid funds experience significantly greater outflows than liquid funds. Consequently, these outflows intensify liquidation lag that negatively impacts NAV, generates a run incentive, and creates a feedback loop with further outflows.

This paper offers new empirical evidence contributing to the mutual fund and financial regulation literature. First, corporate bond funds are vulnerable to run behavior, as illiquid funds experience greater outflows upon poor performance compared to liquid funds. Second, institutional bond funds exhibit a greater degree of run behavior than retail funds, as flows into institutional funds are less sensitive to performance but more sensitive to illiquidity. Institutional investors are less return-chasing than retail investors but more responsive to illiquidity, evidence that institutional bond funds may be more vulnerable to runs. Third, the illiquidity of a bond fund's underlying holdings and its level of cash reserves are significant predictors of run incentives and future NAV. The NAV of a bond fund with extremely illiquid holdings is several times more sensitive to outflows than that of a bond fund with average-liquidity holdings. Additionally, the lack of a sufficient cash buffer intensifies this relationship, as unusually large redemptions generate fire sales and severe liquidation lag.

These results shine light on the importance and capability of bond funds in presenting systemic risk. The primary systemic concern is not necessarily a full-scale run on a bond fund, but rather the refusal of bond funds, in anticipation of the lag effects explored in this paper, to roll over and supply corporate credit. In the case of MMMFs in the latest financial crisis, large investor redemptions led MMMFs to cut short-term financing to broker-dealer firms and other large financial institutions. These institutions' inability to roll over their short-term debt led to defaults, bankruptcy, fire sales, and contagion. Analogously, an economic shock followed by widespread investor redemptions may prompt bond funds, in anticipation of the lag effects, to stop the normal rollover of corporate credit. The taper tantrum in summer 2013 created an example of such a phenomenon. Bond funds experienced unprecedented outflows, prompting massive asset liquidations, and businesses were unable to issue debt due to widening and volatile yield spreads. Thus, corporations' inability to access the credit markets may create panic that may seriously harm the real economy.

However, some argue that large asset managers would be immune to run behavior by any individual fund, since these firms usually manage hundreds of different mutual fund vehicles. While possible that large asset managers are well-diversified, a run or failure of one fund could still trigger market panic across the asset managers' other funds. In other words, if asset manager *A* has bond fund *z* that fails from a run, investors may be strongly motivated to withdraw from *A*'s other funds as well. Market panic, a central idea to the bank run literature, can be self-fulfilling. Even if *A*'s other funds are indeed safe due to diversification, self-driven fear may be sufficient to lead to the run equilibrium.

This paper focuses on liquidation lag as the key driver of run incentives in bond funds. However, alternate mechanisms can further amplify these incentives, such as contagion effects, leveraged investors, market panic, etc. These are left to future research but would likely strengthen the channels put forth in this paper. Although bond funds have not triggered a crisis in the past, it would be unwise to dismiss all possibility in the future. History has shown that when market participants act by conditioning upon the past, believing that something that has never happened will never happen, the market can respond in the most detrimental and bizarre ways.

Lastly, these findings encourage further discussion and research into how policymakers and regulators might mitigate run incentives in large and growing asset managers. Although it may be challenging for regulators to change the structure of open-end funds, uniquely characterized by investors' ability to buy and sell shares at NAV, it may be appropriate to set an exit fee on redemptions that internalizes the negative externality. The empirical results in Chapter 5.3 argue that run incentives are driven by the illiquidity of underlying assets and the level of cash reserves. A policy sets an exit fee for specific funds, as a function of 1) a fund's underlying illiquidity and 2) amount of cash holdings, may eliminate the incentive for investors to run. For example, funds holding illiquid assets and little cash could be required to set a higher exit fee for its investors than funds holding liquid assets and plenty of cash. Opponents may argue that these exit fees already exist in many funds and do not eliminate the run incentive. While true that a handful of funds impose these fees, they are not enforced by a central authority but rather set internally via the fund's profit-maximizing strategies. The forces of perfect competition in the mutual fund industry naturally incentivize funds to lower fees or eliminate them altogether in order to win more investors, grow AUM, and earn additional revenue – incentives that work against internally-set exit fees in preventing runs. However, a competitive mutual fund industry could in fact be an advantage, making exit fees more effective by reducing excess risk-tasking. For example, funds that wish to hold less cash and make riskier investments would be required to charge higher exit fees, a decision that may push away current and potential investors and therefore decrease the asset manager's revenues. Therefore, to maximize profits, funds would have to be more cognizant of excess risk-taking and the illiquidity of their assets, while making sure to hold sufficient cash and treasuries. Thus, a regulatory exit fee would be economically significant and could efficiently curtail run behavior and run incentives. Other potential measures include limiting the amount of redemptions for a certain period of time or requiring investors to register redemptions several days prior, both of which could decrease the amount of turbulent trading post-redemption and mitigate the effect of liquidation lag.

Although bond funds may not trigger a financial crisis in the same way as a bank failure, their rapid growth, vulnerability to volatile flows, and presence of run incentives make them susceptible to economic downturns and therefore important to the health of the financial markets and real economy. Policymakers should include such bond funds in the regulation dialogue and take measures to mitigate run behavior and run incentives to better ensure financial stability.

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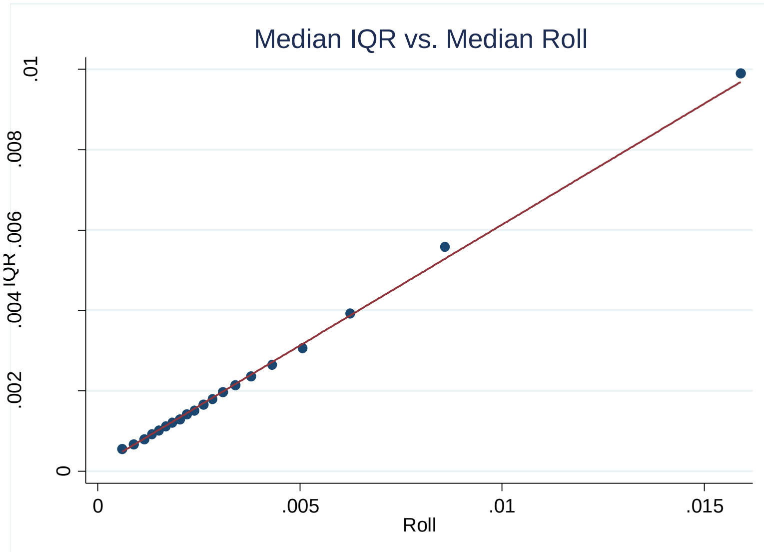
Appendix

Robustness Check for IQR



The above is a bin-scatter plot of median IQR vs. median Roll for each bin (20 bins shown) and shows that IQR is indeed correctly measuring bid-ask spread. Both IQR and Roll are winsorized at the 1 and 99th percentiles and are strongly correlated with a correlation coefficient of 0.932.

Liquidation Lag in (5) ≤ Liquidation Lag in (9)

The effect of liquidation lag in funds with insufficient cash to meet redemption demands is necessarily greater than or equal to that in funds with sufficient cash.

Suppose that (5) > (9)

$$\left(\frac{\lambda}{1-\lambda}\right)\frac{R_1\left(c(R_1-1)+sR_1-I_1\right)}{R_1-sR_1+I_1} > \frac{\left(\frac{\lambda R_1^2\cdot c}{1-\lambda}\right)+R_1 f(1+\delta\lambda)}{R_1-sR_1+I_1}$$

$$\left(\frac{\lambda}{1-\lambda}\right)R_1\left(c(R_1-1)+sR_1-I_1\right) > \left(\frac{\lambda R_1^2\cdot c}{1-\lambda}\right)+R_1 f(1+\delta\lambda)$$

On the LHS, $c \geq sR_1 - I_1$ and $0 \geq sR_1 - I_1 - c$

$$\lambda R_1\left(c(R_1 - 1) + sR_1 - I_1\right) > \lambda R_1^2 c + \left(1-\lambda\right) R_1 f\left(1+\delta\lambda\right)$$

$$\lambda R_1\left(c(R_1 - 1) + sR_1 - I_1\right) - \lambda R_1^2 c > \left(1-\lambda\right) R_1 f\left(1+\delta\lambda\right)$$

$$\lambda\left(R_1 \cdot c + (sR_1 - I_1 - c) - R_1 \cdot c\right) > \left(1-\lambda\right) f\left(1+\delta\lambda\right)$$

$$0 > \left(1-\lambda\right) f\left(1+\delta\lambda\right)$$

$$\textit{contradiction } f \geq 0, 0 \leq \lambda < 1, \delta \geq 1$$

It follows that the effect of liquidation lag when net outflows ≥ cash, as in (9) ≥ effect of liquidation lag when cash is sufficient, as in (5).