Monetary Policy and Fragility in Corporate Bond Funds *

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Abstract

This paper examines the flow patterns in corporate bond mutual funds under different monetary policy environment. We build a model of runs in funds with uncertain future interest rate, uncovering a novel outflow-to-interest-rate relationship. Consistent with the model's predictions, we empirically find that outflows from funds increases when the fed funds target rate increases, the outflow-to-rate sensitivity is stronger under more accommodative and uncertain monetary policy environment, and these monetary-policy-induced flow sensitivities are greater when bond market is more liquid. Our results suggest that fragility in corporate bond funds could be an important unintended consequence of monetary policy.

Keywords: monetary policy, corporate bond mutual funds, fund redemption, financial fragility, market liquidity

1 Introduction

Since the financial crisis of 2008, the Federal Reserve has been actively maintaining a low federal fund target rate to ease the financing conditions of the real sector. Nevertheless, there has been concerns made by academics and regulators regarding various potential negative consequences of the expansionary monetary policy.[1] This paper studies how the looseness and uncertainty in monetary policy might lead to instability in an increasingly important part of the financial intermediation system, namely, the corporate bond mutual fund sector.

Corporate bond mutual fund as an asset class has experienced dramatic growth in recent years. From 2008 to 2017, the total asset under management in corporate bond mutual funds has gone up by three times, reaching \$2 trillion, while the outstanding corporate bond has only increased from \$5.4 trillion to \$8.5 trillion over the same period, according to SIFMA. Its ever-growing size has raised much attention from regulators and researchers about its potential as a threat to the stability of the financial system as a whole. The most salient concern is that fund investors have incentives to redeem their shares ahead of others, resulting in coordinated redemption demands. This phenomenon, also known as "runs on the fund", can cause sizable sales of the corporate bonds in illiquid over-the-counter markets (see Chen, Goldstein, and Jiang 2010; Goldstein, Jiang, and Ng 2017). We share the same concern and show that, interestingly, one source of such fragility in corporate bond funds could be the very monetary policy designed by central bankers.

In the first half of the paper, we build a model of runs on bond funds to show how monetary policy can affect the likelihood of fund runs. Runs happen because there is a first-mover advantage in fund investors' redemption decisions. When an investor redeems her fund share, she gets the net-asset-value (NAV), based on the market value of the assets on the fund's balance sheet, as of the day of redemption. When the fund tries to sell the assets to satisfy the redemption, however, the

[1] Adrian and Shin (2008) shows that an accommodative monetary policy increases intermediaries' incentives to take leverage. Di Maggio and Kacperczyk (2016), Choi and Kronlund (2017) and Ivashina and Becker (2015) document risk-taking behaviors of money market funds, corporate bond mutual funds, and insurance companies over zero interest rate periods, , respectively. Daniel, Garlappi, and Xiao (2018) document retailer investors reaching-for-income by increasing investing in high-dividend stocks and high-yield bond under low-interest-rate monetary policy.

assets often can only be sold at a substantial discount, especially for illiquid assets like corporate bonds. As a result, redeeming investors impose losses on the remaining ones, prompting the latter to redeem as soon as possible when they receive some signals that suggest others' redemption. While existing works have primarily focused on past fund performance as one of such signals, we look at another natural signal, namely, future interest rate shocks.

We show that when investors receive private signals about future interest rate changes, they would redeem en masse from the fund when the signals suggest a high enough interest rate. Observing a (signal of) high interest rate shock makes redemption at the NAV attractive for two reasons. First, it implies that the bond price, and thus, the value of the fund share will be relatively low. Second, the NAV, which is based on the *expected* bond price, contains a premium over the *realized* bond price at the expected interest rate, due to the uncertainty in future interest rate and the convexity of bond price.

We then establish the paper's main results that more accommodative and uncertain monetary policy environment increases the incidence of coordinated redemption in bond funds caused by interest rate changes. This is because, by Jensen's inequality, the premium in the NAV is larger when the bond price is more convex, which is when the current interest rate is lower, and when the volatility of interest rate shocks is higher. A larger premium in turns incentivizes investors to redeem.

The last set of analytical results show that market illiquidity mitigates the monetary-policy-induced fund fragility discussed above. Intuitively, illiquidity itself encourages redemptions, as the losses imposed on the remaining investors become more substantial. The bond price thus has to increase substantially more to deter investors' redemption. In this case, a loose monetary policy may help because bond price increases more for the same interest rate drop. The same for monetary policy uncertainty since a large enough interest rate drop is more likely.

In the second half of the paper, we empirically test all the model's predictions discussed above using corporate bond mutual fund data from 1992 to 2017. We find strong empirical support to all the predictions. First, we document a significantly positive relation between outflows from the corporate bond funds and the change in Fed funds target rate. On average, a 1% increase in Fed funds target rate (TFF) is accompanied with 1.077% incremental outflows, roughly 18.15 Billion USD benchmarked to the total size of corporate bond mutual funds in 2017. This result suggests that interest rate changes can cause coordinated redemption in bond funds.

Next, we find the outflow-to-Fed-funds-target-rate relation is much stronger in an accommodative and uncertain monetary environment. Specifically, during periods with low TFF rates, a 1% increase in TFF is associated with 4.174% incremental outflows; while during policy periods with high TFF rates, the positive relation disappears. Similarly, when monetary policy uncertainty is high, a 1% increase in TFF is associated with 2.675% incremental outflows, while outflow-to-Fed-funds-target-rate relation even overturns (insignificantly) when monetary policy uncertainty is low. Moreover, looseness and uncertainty of monetary policy also have complementary effects on bond mutual fund fragility.

Lastly, we provide evidence that market illiquidity, proxied by high VIX, weakens fragility induced by monetary policy looseness and uncertainty. In months with high VIX and low Fed funds target rate, the change in TFF is not associated with outflow at all, while the average effect in a low Fed funds rate regime is 4.174%. Similarly, in months with high VIX and high monetary policy uncertainty, a 1% increase in TFF is only associated with 0.841% incremental outflows, significantly smaller than the average effect of 2.675% reported in a high monetary policy uncertainty regime. Similar effects are found with other proxies for illiquidity.

Literature review This paper closely relates to existing works on financial fragility of open-end mutual funds, which stems from the investors' payoff complementarities in redemptions. Chen, Goldstein, and Jiang (2010) focuses on how asset illiquidity increases the payoff complementarities and thus fragility in funds. Liu and Mello (2011) and Zeng (2016) study the optimal liquidity management of funds to reduce fragility. Morris, Shim, and Shin (2017) asks when fund managers should hoard cash in anticipation of redemptions in the future. These models and empirical evidence look at flow-to-performance relationship, while we contribute by focusing on the effect of monetary policy and documenting a novel flow-to-interest-rate relationship.

The only papers modeling monetary policy and asset management sector together are Morris and Shin (2017) and Feroli et al. (2014). Their mechanism to generate strategic complementarities is through short-term relative performance rankings among asset managers. Due to the strategic complementarities, the model engenders a jump in the yield of the risky bond. In contrast, our model presents a novel mechanism which builds a direct bridge between monetary policy and fund fragility.

Second, this paper contributes to the recent growing literature on the effect of monetary policy on the behavior of non-banking financial intermediaries. Liang and Nellie (2017) provides an excellent survey. They highlight the endogenous risk-taking channel under an expansionary monetary policy for non-banking financial intermediaries. For example, Adrian and Shin (2008) shows that an accommodative monetary policy increases intermediaries' incentives to take leverage. Di Maggio and Kacperczyk (2016), Choi and Kronlund (2017) and Ivashina and Becker (2015) document risk-taking behavior of money market funds, corporate bond mutual funds, and insurance companies over zero interest rate periods, respectively. This paper emphasizes that even without risk-taking or reaching-for-yield behavior by financial institutions, looser and more uncertain monetary policy environment could contribute to financial fragility in corporate bond funds because it strengthens the fund investors' incentives to redeem.

Third, this paper belongs to the literature of empirically testing fund fragility. Shin, Adrian, and Arturo (2018) identify the impacts of investors' redemptions on fire sale discount in corporate bond markets, suggesting the existence of negative externalities in bond markets. Similarly, Feroli et al. (2014) finds that fund outflows are positively correlated with declines in NAV, creating incentives for bond investors to leave fund simultaneously. Chen, Goldstein, and Jiang (2010) and Goldstein, Jiang, and Ng (2017) use outflow-to-poor-performance relationship as a proxy for strategic complementarities among fund investors. Using structural recursive vector autoregression (VAR), Banegas, Montes-Rojas, and Siga (2016) also find that bond fund flows instrumented by the unexpected monetary policy are closely related fund performance, indicating a first-mover advantage among investors.

At more micro level, Schmidt, Timmermann, and Wermers (2016) use daily money market mutual fund flow data to examine fund runs in money market mutual funds. Our paper provides further evidence on how monetary policy affects corporate bond fund fragility.

The remainder of the paper is organized as follows. Section 2 presents the model and testable hypotheses. Section 3 presents the empirical analysis and tests the model's predictions. Section 4 concludes.

2 A Model of Fund Run

In this section, we develop a model of runs in an open-ended bond mutual fund caused by interest rate shocks. Our analysis focuses on how different monetary policy environment affects the run sensitivity with respect to these interest shocks, i.e., the fragility of the bond mutual fund.

2.1 The Setup

There are three dates: T_0, T_1 and T_2. There is one good "cash" and no time-discounting.There is only one type of asset traded in the market, namely, zero-coupon long-term bonds ("bonds") with face values 1 and maturity at T_2. For simplicity and to focus on the effect of monetary policy, we assume the bond has no credit risks.

Monetary Policy Monetary policy in our model is summarized by three parameters. r is the one-period (net) interest rate from T_0 to T_1. It is known at T_0 and represents the *tightness* of the monetary policy environment. $r + \sigma\tilde{v}$ is the future one-period interest rate from T_1 to T_2, which is unknown at T_0 because the *interest rate shock* $\tilde{v}$ is a random variable to be realized at T_1. T_1 corresponds to the date of the FOMC meeting, at which the Federal Reserve publicly announces the new interest rate $r + \sigma\tilde{v}$. We assume that $\tilde{v}$ is drawn from a uniform distribution with with zero mean, unit variance, that is, $\tilde{v} \sim U(-\frac{\sqrt{12}}{2}, \frac{\sqrt{12}}{2})$. The parameter $\sigma > 0$ captures the *monetary policy uncertainty* over T_1 and T_2.

Investors and a bond fund There is a continuum of risk-neutral investors. Each investor has one unit of cash invested in an open-ended mutual fund. Thus, each of them owns a share of the fund, which could be redeemed upon their request right before T_1 or held to T_2 to share the fund's assets.[2]

The open-ended mutual fund ("the fund") acts as an investing intermediary of the bonds. We assume that the fund invests all the cash received from investors in the bond at T_0, buying $\frac{1}{p_0}$ units of the bonds at the price p_0. The nature of "open-endedness" allows investors to redeem their shares at the fund's latest net asset value (NAV), which is the market value of the fund's total assets.

NAV, bond illiquidity, and redemption externality Right before T_1, i.e., before the interest rate shock $\tilde{\nu}$ realizes, the bond price is $\bar{p}_1 \equiv \mathbb{E}\left[\frac{1}{1+r+\sigma\tilde{\nu}}\right]$ and the NAV of the fund share is $\frac{1}{p_0}\bar{p}_1$. Investors have the right to redeem their shares at this NAV. Then, at T_1, the central bank announces the new interest rate and the bond price adjusts to $p_1 = \frac{1}{1+r+\sigma\nu}$, where ν is realized shock. To repay the redeeming investors, the fund needs to liquidate some bonds at the price $\mathcal{L}p_1$. The exogenous liquidation discount factor $\mathcal{L} \in [0,1]$ reflects the illiquidity of the bond market, stemming from inventory cost of market maker, search costs in the over-the-counter market, and bargaining power of the counterparties.

The options granted to investors to redeem at the NAV, which is based on the current market price of the bond $\bar{p}_1$, imply that redemptions will lead to loss incurred by the remaining investors when the price at the times of the bond sales p_1 is below $\bar{p}_1$. This redemption externality is further magnified when the bond market becomes more illiquid (lower $\mathcal{L}$), and gives rise to strategic complementarity in investors' redemption decisions. We describe the redemption game and investors' payoffs below.

The redemption game and investors' payoffs Right before T_1, the interest rate shock is realized and has not been announced by the central bank. Each investor observes a private signal about the realized shock ν and then individually decides whether to redeem their share or not. The information structure will be discussed formally in Section 2.2. Redeeming investors have a claim to receive the

[2] We abstract away from the investors' decision to invest in the fund in the first place. Relative to direct investment in the bond, investing via the fund could have advantages of lower transaction costs and better diversification benefits.

NAV $\frac{\bar{p}_1}{p_0}$ at T_1 and the non-redeeming investors share the fund's remaining cash flow at T_2.

An investor's payoff from redemption and staying depend on how many other investors redeem, the realized interest rate shock hence the price of the bond p_1, and the liquidation discount $\mathcal{L}$. Suppose fraction $\lambda \in [0, 1]$ of investors redeem. To satisfy the redemption claims $\lambda\frac{\bar{p}_1}{p_0}$, the fund has to sell $\lambda\frac{\bar{p}_1}{p_0}\frac{1}{\mathcal{L}p_1}$ units of bond. There is enough bond and hence the fund is not completely liquidated if and only if

$$\frac{1}{p_0} \geq \lambda\frac{\bar{p}_1}{p_0}\frac{1}{\mathcal{L}p_1} \iff \lambda \leq \frac{\mathcal{L}p_1}{\bar{p}_1}. \tag{1}$$

The payoff of fund investors at T_2 is summarized in Table 1. If $\lambda \leq \frac{\mathcal{L}p_1}{\bar{p}_1}$, a redeeming investor receives the NAV $\frac{\bar{p}_1}{p_0}$ and re-invests the proceeds in a bond, getting a return $\frac{1}{p_1}$. The fund continues to hold $\frac{1}{p_0} - \lambda\frac{\bar{p}_1}{p_0}\frac{1}{\mathcal{L}p_1}$ units of the bond, and the proceeds are shared by $(1 - \lambda)$ staying investors. If $\lambda > \frac{\mathcal{L}p_1}{\bar{p}_1}$, the fund is completely liquidated. The total liquidation proceeds $\frac{1}{p_0}\mathcal{L}p_1$ is shared and re-invested by λ redeeming investors, while a staying investor receives nothing at T_2.

	$\lambda \leq \frac{\mathcal{L}}{\bar{p}_1} \times p_1$	$\lambda > \frac{\mathcal{L}}{\bar{p}_1} \times p_1$
Redeem	$\frac{\bar{p}_1}{p_0}\frac{1}{p_1}$	$\frac{\mathcal{L}p_1}{p_0\lambda}\frac{1}{p_1}$
Stay	$\frac{1}{p_0(1-\lambda)} \times \left(1 - \frac{\lambda\bar{p}_1}{\mathcal{L}p_1}\right)$	0

Table 1: The payoff of investors at T_2.

It is immediate to see from Table 1 the redemption externality imposed by redeeming investors on the staying investors, and how it is magnified by bond illiquidity. Staying investors' payoffs first decrease in λ and then become zero when λ is high enough. Moreover, when the bond is less liquid (lower $\mathcal{L}$), the payoffs decrease at a high rate and reach zero earlier.

2.2 Equilibrium

Given the investors' payoffs, we are ready to characterize the investors' optimal redemption strategies and solve for equilibrium. We first show that there exists multiple equilibria if investors observe the interest rate shock perfectly. Then, by introducing idiosyncratic noises in investors' private signals, we characterize the unique equilibrium in which investors follow a threshold strategy. This so-called global-game technique allows us to compute the ex ante probability of runs on the bond mutual fund, which we interpret as the fragility of the bond fund.

2.2.1 Multiple equilibria under perfect signals

Suppose right before T_1, the interest rate shock is realized to be ν and all investors receive perfect signals about the shock, i.e., $s_i = \nu$ for all i. In this case, there are three regions in which investors' optimal redemption strategy differs.

The first region is a high-ν region. When $\nu \geq \bar{\nu}$, redemption is the dominant strategy. That is, it is optimal for an investor to redeem even when all investors stay ($\lambda = 0$). The critical value $\bar{\nu}$ is implicitly defined by

$$\frac{\bar{p}_1}{p_0}\frac{1}{p_1} > \frac{1}{p_0} \Leftrightarrow \nu \geq \bar{\nu} \equiv \frac{1}{\sigma}\left(\frac{1}{\bar{p}_1} - (1+r)\right). \tag{2}$$

Intuitively, when the interest rate is high enough, or, the bond price is low enough, redeeming the fund share at the NAV is very attractive. Thus, all investors redeeming is the only equilibrium.

Similarly, when $\nu < \underline{\nu}$, the price of the bond is so high that even all other investors redeem ($\lambda = 1$), the fund has enough bond to liquidate and repay the redeeming investors. That is,

$$\lambda = 1 < \frac{\mathcal{L}p_1}{\bar{p}_1} \Leftrightarrow \nu < \underline{\nu} \equiv \frac{1}{\sigma}\left(\frac{\mathcal{L}}{\bar{p}_1} - (1+r)\right). \tag{3}$$

In this region, staying is the dominant strategy and hence all investors staying is the only equilibrium.[3]

Finally, there is an non-empty region with intermediate value of $\nu \in (\underline{\nu}, \bar{\nu})$ if $\mathcal{L} < 1$. In this region, multiple equilibria exist. All investors redeem in one equilibrium and all of them stay in the

[3] The payoff of staying $\lim_{\lambda\to 1} = \frac{1}{p_0(1-\lambda)}\left(1 - \frac{\bar{p}_1}{\mathcal{L}p_1}\right) \to \infty$, is higher than the payoff of redemption, $\frac{\bar{p}_1}{p_0}\frac{1}{p_1}$.

other. To see this, it is useful to define the payoff difference between redeeming and staying for an investor as

$$\Delta\pi(\lambda) = \begin{cases} \frac{\bar{p}_1}{p_0}\frac{1}{p_1} - \frac{1}{p_0(1-\lambda)} \times \left(1 - \frac{\lambda \bar{p}_1}{\mathcal{L} p_1}\right) & \text{if } 0 \leq \lambda \leq \frac{\mathcal{L} p_1}{\bar{p}_1} \\ \frac{\mathcal{L}}{p_0 \lambda} & \text{otherwise.} \end{cases} \tag{4}$$

Notice that $\Delta\pi(0) < 0$ and $\Delta\pi(1) > 0$, implying that it is optimal to redeem (stay) if all other investors redeem (stay). In summary, there exist multiple equilibria when $\nu \in [\underline{\nu}, \bar{\nu}]$.

Lemma 1 (Multiple equilibria under common knowledge). *When $\mathcal{L} < 1$, there exists a region $\nu \in [\underline{\nu}, \bar{\nu}]$ in which multiple equilibria exist.*

Proof. See the Appendix C.1 □

2.2.2 Global game and fragility of bond fund

In order to compute the likelihood of the run equilibrium and study the effect of monetary policy on it, we apply the global-game techniques and achieve unique equilibrium in which investors follow an optimal threshold strategy. Specifically, we assume that investors receive noisy signals s_i about the realized interest rate ν right before T_1, given by

$$s_i = \nu + \sigma_\varepsilon \varepsilon_i,$$

where $\sigma_\varepsilon > 0$ is a parameter that captures the size of noise, and ε_i is an idiosyncratic component which has a cumulative distribution $F_\varepsilon(\cdot)$. The noise terms $\{\varepsilon_i\}$ are independent across investors, and its density function $f_\varepsilon(\cdot)$ is assumed log-concave to guarantee the monotone likelihood ratio property (MLRP).

Following Goldstein and Pauzner (2005), one can show that there exists a unique symmetric equilibrium, in which there is a cutoff threshold ν^* such that every investor redeems from the fund if her signal is above the threshold and stays otherwise. This threshold strategy is as follows:

$$\begin{cases} \text{Redeem} & s_i > v^* \\ \text{Stay} & s_i \leq v^*. \end{cases}$$

The equilibrium threshold signal $v^*$is determined by the condition that the investor who has the threshold signal is indifferent between redeeming or staying. In other words, the expected net payoff $\Delta\pi(\lambda)$ given signal v^* is:

$$\int_\lambda \Delta\pi(\lambda) f_{\lambda|v^*} d\lambda = 0. \tag{5}$$

As common in the literature, our analysis focuses on the case in which the noises in signals become arbitrarily close to zero. As $\sigma_\varepsilon \to 0$, investors observe the realized shock v with almost perfect precision and the threshold signal approaches some state v^*. In other words, in equilibrium all investors redeem if and only if the realized interest rate shock v is above the threshold v^*. Moreover, as explained in details in Morris and Shin (2003), v^* can be characterized easily by using (5), because for the investor who has the threshold signal v^*, λ is uniformly distributed over $[0, 1]$. Finally, one can easily compute the ex ante probability of fund run, which is our notion of fragility, by using the prior distribution of the interest rate shocks $\tilde{v}$. We summarize these results in Proposition 1.

Proposition 1 (Unique threshold equilibrium under incomplete information). *For $\sigma_\varepsilon \to 0$, there is a unique perfect Bayesian equilibrium for investors. In this equilibrium, for realization of $v > v^*$, all investors redeem ($\lambda = 1$). For realization of $v \leq v^*$, all investors stay ($\lambda = 0$). The threshold v^* is characterized by*

$$\frac{1}{1 + r + \sigma v^*} = \bar{p}_1 g(\mathcal{L}) \tag{6}$$

where $g(\mathcal{L})$ decreases in $\mathcal{L}$, $\lim_{\mathcal{L}\to 1} g(\mathcal{L}) = 1$, and is the unique solution to

$$\mathcal{L}\left(\mathcal{L} + \mathcal{L}\log\left(\frac{1}{g(\mathcal{L})\mathcal{L}}\right) - 1\right) - \left(\frac{1}{g(\mathcal{L})} - \mathcal{L}\right)\log\left(1 - \mathcal{L}g(\mathcal{L})\right) = 0. \tag{7}$$

The fragility of the fund is defined as the likelihood that all investors redeem and thus the fund is fully liquidated, i.e., $\mathbb{P}(v > v^*)$.

Proof. See the Appendix C.2 □

Proposition 1 delivers sharp predictions on investors' equilibrium behavior and illustrates clearly the economic forces of the model. By re-writing (6), using the definition of the bond price for a given realized shock $p_1(\nu) = \frac{1}{1+r+\sigma\nu}$, and pre-multiplying on both sides the number of bonds $\frac{1}{p_0}$ the fund initially owns, all investors redeem in equilibrium if and only if

$$\frac{1}{p_0}\bar{p}_1 g(\mathcal{L}) > \frac{1}{p_0}p_1(\nu). \tag{8}$$

This condition is intuitive. It says that all investors redeem and hence the fund is completely liquidated when the NAV of the fund $\frac{1}{p_0}\bar{p}_1$, scaled up by a factor $g(\mathcal{L}) \geq 1$, is greater than the intrinsic value of the fund $\frac{1}{p_0}p_1(\nu)$. When the bond market is perfectly liquid ($\mathcal{L}$ approaches 1), the moderating factor $g(\mathcal{L})$ becomes 1. The condition boils down a simple arbitrage condition $\bar{p}_1 > p_1(\nu)$, saying that investors, who essentially observe the true value of the bond, redeem the shares whenever the NAV (per unit of bond) is above the bond's value. When the liquidity of bond decreases, the moderating factor $g(\mathcal{L})$ increases, implying that investors redeem the shares in equilibrium even if the NAV is below the true value of the bond. This is because of the redemption externality discussed before. When the fund has to liquidate the bond at a discount to repay the redeeming investors, investors who stay have to incur the losses. Taking these losses into account, investors optimally choose to redeem for a larger range of realized interest rate shocks. Therefore, we henceforth refer $g(\mathcal{L})$ as the *coordination risk* factor.

Once the critical value of the interest rate shock ν^* is pinned down, we can compute the ex ante probability of the equilibrium in which all investors redeem, i.e., $\mathbb{P}(\tilde{\nu} > \nu^*)$. As in Chen, Goldstein, and Jiang (2010), we interpret this measure as the fragility of the fund.

2.3 Fragility in funds under different monetary policy environment

In this section, we study how fragility in bond mutual funds responds to different monetary policy environment and market liquidity conditions. The results of these analysis will give sharp empirical predictions of the model, which will be tested in Section 3.

We look at whether a more accommodating and/or uncertain monetary policy has an impact on financial fragility in bond funds. In our model, a lower current interest rate r represents a looser monetary policy environment and a higher volatility σ for the interest rate shocks proxies for higher uncertainty in the monetary policy.

Corollary 1 (Effects of monetary policy on fragility). *There exists a $\tilde{\mathcal{L}} \in (0, 1)$ such that*

a. $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial(-r)} > 0$ *for* $\mathcal{L} \in [\tilde{\mathcal{L}}, 1]$ *and* $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial(-r)} < 0$ *otherwise;*

b. $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial \sigma} > 0$ *for* $\mathcal{L} \in [\tilde{\mathcal{L}}, 1]$ *and* $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial \sigma} < 0$ *otherwise;*

c. $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial \sigma \partial(-r)} > 0$*;*

d. $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial(-r)\partial(-\mathcal{L})} < 0$ *and* $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial \sigma \partial(-\mathcal{L})} < 0$.

Proof. See the Appendix C.3. □

Corollary 1 contains the key results fo the paper. It first states that when the bond market is relatively liquid ($\mathcal{L} > \tilde{\mathcal{L}}$), a looser (lower r) and more uncertain (higher σ) monetary policy environment increases the fragility of bond funds. Then, the effects from the two distinct dimensions of the monetary policy reinforce each other. Finally, market illiquidity (lower $\mathcal{L}$) weakens such monetary-policy-induced fragility.

One can gain some insights on how the looseness of monetary policy affects financial fragility from the condition for fragility in (8). Intuitively, fragility is about how negative the realization of the shock v has to be, so that the realized bond price $p_1(v)$ is at least as high as the NAV (per bond) $\bar{p}_1$ scaled up by the coordination risk factor $g(\mathcal{L})$. Suppose for now the market is perfectly liquid, and thus $g(\mathcal{L}) = 1$. Consider a loosening of the monetary policy, i.e., from a high-r to a low-r environment. The difference between the NAV (per bond) $\bar{p}_1$ and the bond price at the expected shock $p_1(0)$ becomes larger. This is due to Jensen's inequality and the fact that the bond price is more convex in the low-r environment. As a result, the threshold shock that equalizes realized bond price $p_1(v^*)$ and the NAV $\bar{p}_1$ has to be more negative, implying a higher fragility $\mathbb{P}(\tilde{v} > v^*)$.

When the market is illiquid enough, i.e., $g(\mathcal{L})$ sufficient higher than 1, the result is reversed. In the high-r regime, the bond's sensitivity to interest rate shock (duration) is low. Thus, the interest rate shock has to be very negative to push the bond price enough to be above the scaled-up NAV. In this case, the bond's higher duration in the low-r regime helps to prevent fragility. Put differently, as the market become more illiquid, the fragility concern from coordination risk becomes more important and counteracts the fragility arising from the Jensen's effect associated with loose monetary policy environment, i.e. $\frac{\partial \mathbb{P}(\tilde{v} > v^*)}{\partial(-r)}$ becomes less positive when $\mathcal{L}$ decreases.

A similar comparison between the effect from Jensen's inequality on the NAV and how negative the shocks v has to be to stop investors' redemption applies to an increase in the monetary policy uncertainty σ. The result that low-r and high-σ reinforce each other's impact also follows intuitively from the Jensen's effect.

2.4 Summary of main hypotheses

In summary, using the results from Proposition 1 and Corollary 1, we formulate the following testable hypotheses and test them in Section 3. Following Chen, Goldstein, and Jiang (2010) and Goldstein, Jiang, and Ng (2017), we proxy the existence of fragility with a positive outflow-to-interest-rate relationship, and the increase of fragility with a greater outflow-to-rate sensitivity.

- *Hypothesis 1:* There is a positive relationship between fund outflows and interest rate shocks.
- *Hypothesis 2:* The outflow-to-rate sensitivity is stronger in a looser monetary policy environment, when the market is relatively liquid.
- *Hypothesis 3:* The outflow-to-rate sensitivity is stronger in a more uncertain monetary policy environment, when the market is relatively liquid.
- *Hypothesis 4:* There is a complementary effect on outflow-to-rate sensitivity between looseness and uncertainty in monetary policy environment.
- *Hypothesis 5:* Market illiquidity weakens the increase in outflow-to-rate sensitivity due to looseness and uncertainty in monetary policy environment.

3 Empirical Investigation

In this section, we empirically test the model's main hypotheses listed in Section 2.4.

3.1 Data Sources

Corporate bond mutual funds Data on corporate bond mutual funds are extracted from the Center for Research in Security Prices (CRSP). The sample period includes 312 months from January 1992 to December 2017, as there are few corporate bond mutual funds in the database prior to 1991. The dataset contains detailed monthly returns and monthly total net asset (TNA) values for each fund share, as well as its quarterly fund share characterizes, such as fund fees, holdings, front and rear loads. Following Goldstein, Jiang, and Ng (2017), we select corporate bond mutual funds based on their Lipper objective codes provided by CRSP. [4] Index corporate bond mutual funds, exchange-traded funds, and exchange-traded notes are excluded. Our final sample contains 5228 unique fund share classes (1853 unique corporate bond mutual funds).[5]

The net fund flow of fund i at month t is calculated as

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

where $R_{i,t}$ is the return of fund i over month t, and $TNA_{i,t}$ is the total net asset value at the end of month. As the standard practice, fund flows are winsorized at the 1% and 99% levels, to mitigate the influence of outliers.

As documented by Goldstein, Jiang, and Ng (2017), there exists a strong positive relation between fund flows and past performances of corporate bond mutual funds. We hence control for past performance. The performance of fund i at month t is measured as the past one year's alpha

[4] A mutual fund share is considered as corporate bond fund share if 1) its Lipper objective code in the set ('A', 'BBB','HY', 'SII', 'SID', 'IID'), or 2) its Strategic Insight Objective code in the set ('CGN','CHQ','CHY','CIM','CMQ','CPR','CSM'), or 3) its Wiesenberger objective code in the set ('CBD','CHY'), or 4) its CRSP objective code start with 'IC'.

[5] We remove fund-month entries without return or TNA information, and discard fund-month entries with more than 100% increase or decrease in TNA over a month. To be included in the final sample, the fund share must exist more than one year within our sample period. Note that as we use one year data to estimate the performance of an individual fund share, our raw sample starts from January 1991.

from the following time-series regression:

$$R^e_{i,\tau} = Perf_{i,t-12\to t-1} + \eta_B R^e_{B,\tau} + \eta_M R^e_{M,\tau} + \varepsilon_{i,\tau}, \quad \tau \in (t-12, t-1) \tag{9}$$

where $R^e_{i,\tau}$, $R^e_{B,\tau}$ and $R^e_{M,\tau}$ denote excess returns of the fund, the aggregate bond market and the aggregate stock market, respectively.[6] Specifically, $R^e_{B,\tau}$ is approximated by the Vanguard total bond market index fund return and $R^e_{M,\tau}$ is approximated by CRSP value-weighted market return. The index return data is collected from Bloomberg and CRSP.

Fed Fund Target Rates The US Federal Reserve directly sets Fed funds target rate, which is the rate at which depository institutions (banks) lend reserve balances to other banks on an overnight basis. In this paper, we adopt the Fed funds target rate, extracted from FRED, as a proxy for r.[7] We also extract the dates of Federal Open Market Committee (FOMC) meetings from Federal Reserve website[8]. Our sample covers a total of 312 months, among which 224 months have FOMC meetings.

Monetary Policy Uncertainty Our main proxy for monetary policy uncertainty in the US is the MPU index developed by Husted, Rogers, and Sun (2017), as shown in Figure 3. The MPU index (denoted as "MPU HRS") is constructed by counting keywords related to monetary policy uncertainty in the New York Times, Wall Street Journal and Washington Post. The MPU index spikes around near tight presidential elections, Taper Tantrum, QE1 and QE 2, the 9/11 attacks, and other periods featuring significant monetary policy disruptions.

Liquidity Following Goldstein, Jiang, and Ng (2017), we employ three proxies for corporate bond illiquidity. The first proxy is the index of corporate bond market illiquid index proposed by Dick-Nielsen, Feldhütter, and Lando (2012) (DFL). This index is available July 2002 to December 2017, which is shorter than our sample period. Second, we adopt VIX index from the Chicago Board

[6] The risk-free rate is approximated by 1-month London Interbank Offered Rate (LIBOR).

[7] Before 2008, Fed fund target rate series are used, as listed in page https://fred.stlouisfed.org/series/DFEDTAR. After 2008, a target rate corridor is introduced, we then use the upper limit of Fed funds target rate, as in page https://fred.stlouisfed.org/series/DFEDTARU.

[8] https://www.federalreserve.gov/monetarypolicy/openmarket.htm

Options Exchange (CBOE) as our second measurement of market liquidity, which is 86% correlated with the DFL index. VIX is confirmed in Bao, Pan, and Wang (2011) to positively correlate with the illiquidity of corporate bonds. Third, Brunnermeier and Pedersen (2009) argue that funding liquidity of financial institutions positively affect market liquidity. We therefore use TED spread[9] from FRED as the measure of funding liquidity, which further determines the liquidity of the bond markets.

Other Variables We control for a series of macro drivers for fund flows to the corporate bond mutual funds, inclulding the yield slope, the default spread and the aggregate bond market illiquidity. The yield slope is calculated as the yield difference between the 30-year and one-year Treasury yields and the default spread is the yield difference between BBB- and AAA-rated corporate bonds, both extracted from FRED. Choi and Kronlund (2017) consider these three variables as potential macro drivers for reaching for yield in the corporate bond mutual funds.

Table B.1 presents the summary statistics for the funds in our sample from January 1992 to December 2017. The reported statistics are consistent with Table 1 in Goldstein, Jiang, and Ng (2017).[10]

3.2 Main Empirical Results

The model in Section 2 suggests that the bond mutual fund investors redeem from the funds in anticipation of an increase in the interest rate, which can further accentuate the fragility in bond funds due to the illiquidity of corporate bonds. Therefore, we use outflow-to-fed-funds-target-rate sensitivity ("outflow-rate sensitivity") as the proxy for fund fragility induced by interest rate. This approach is similar to that of Goldstein, Jiang, and Ng (2017), which documents a strong flow-performance relation and adopts it to measure fragility. In the following, we first verify whether

[9] TED rate measures the difference between the three-month London Interbank Offered Rate and the three-month Treasury-bill interest rate.

[10] To mitigate the influence of outliers and false data records in CRSP, we winsorize all the continuous variables of fund characteristics at 1% and 99%. All results in this paper are robust when we winsorize data at 0.5% and 99.5% levels.

there is a positive relation between fund outflows and the change in Fed funds target rates, and then study how the relationship changes in different market conditions, as predicted in Section 2.4.

3.2.1 Bond Fund Fragility

We start with testing Hypothesis 1, which predicts a positive outflow-rate relationship for corporate bond mutual funds. As Fed funds target rate only varies over time, we rely on panel regression with fund fixed effect to exploit how fund flows respond to the change in Fed fund target rate. We perform the following panel regression:

$$OutFlow_{i,t} = \alpha_i + \Delta TFF_t + Controls_t^M + Controls_{i,t}^F + Controls_{i,t}^I + \varepsilon_{i,t} \tag{10}$$

where $OutFlow_{i,t}$ measures the outflows from fund i at month t and the key independent variable ΔTFF_t is the change in Fed funds target rate at month t. To rule out the concerns of omitted variables, we include potential macro-and micro-drivers for fund flows as control variables. Macro controls, $Controls_t^M$, include 1) the term-structure of corresponds bonds, approximated by the change in yield indifference between 30-year and one-year Treasury yield; 2) the default risk, approximated by the change in yield difference between BBB- and AAA-rated corporate bonds; and 3) the bond market illiquidity, approximated by the change in VIX index[11]. Micro controls, $Controls_{i,t}^F$, are fund characteristics, including fund performance from regression (9), last month's fund return, natural log of the total net asset and expense ratio[12]. Lastly, since the model predictions are partial derivatives for a given set of exogenous parameters, we also include the indicator for market conditions $\mathbb{1}$(High MPU^{HRS}), $\mathbb{1}$(High VIX) as control variables. To allow for an intertemporal dependence of flows across funds and across time, we cluster standard errors by both fund share and month.

Columns 1-3 in Table B.2 present the regression results with different specifications. Significant positive loadings on ΔTFF_t confirm the positive relation between outflows and Fed funds target rate. Specifically, a 1% increase in Fed funds target rate is accompanied with 1.077% incremental outflows

[11] In order to keep full sample, we use VIX index as the proxy for bond market illiquidity.
[12] Since we already include fund fixed effect, we do not include fund age which is a deterministic value in time series.

(roughly 18.15 Billion USD benchmarked to the total size of corporate bond mutual funds in 2017). Besides, there are more outflows from the corporate bond mutual funds when the default spread is higher and the bond market is more illiquid. At the fund level, poor past performances and past returns drive the capital out of the funds.

Since the Fed funds target rate is modified only after FOMC meetings, we conduct a robustness analysis in a subsample comprised of months with FOMC meetings only. Columns 4-6 in Table B.2 confirm the strong positive outflow-rate relation. The effect sizes are slightly higher then those in the first three columns. Overall, we find capital flows out from corporate bond mutual funds when Fed funds target rate increase. This is in line with Banegas, Montes-Rojas, and Siga (2016), who find positive monetary policy shocks trigger heavy aggregate outflows from bond funds.

3.2.2 Bond fund fragility induced by loose monetary policy

According to Hypothesis 2, when the bond market is relatively liquid, the fund fragility will be exacerbated in a low Fed fund rate regime compared with a high Fed fund rate regime because of the convexity in bond price, referred to as "bond fund fragility induced by loose monetary policy". To test this hypothesis, we perform the following regression:

$$\begin{aligned} OutFlow_{i,t} &= \alpha_i * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) + \Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) + Controls^M_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) \\ &+ Controls^F_{i,t} * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) + Controls^I_{i,t} * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) + \varepsilon_{i,t}, \quad \forall DFL_t < \overline{DFL_t} \end{aligned} \tag{11}$$

where $OutFlow_{i,t}$ measures the outflows from fund i at month t, ΔTFF_t is the change in Fed funds target rate at month t, $\mathbb{1}(\text{Low}^t\ \text{TFF}_t)$ is an indicator variable that equals one if TFF is below the bottom tercile and zero if it is above the the top tercile over the sample period (see Figure 2), and $Control^M_{i,t}$, $Control^F_{i,t}$, $Control^I_{i,t}$ remain the same as before. To ensure a relative liquid market condition($\mathcal{L} \to 1$), we only consider the sub-sample when bond market illiquidity, measured by DFL index, is below the sample mean. We add interaction terms for all control variables such that the estimation of interactoin term $\Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t)$ is unbiased. To allow for an intertemporal dependence of flows across funds and across time, we cluster standard errors by both fund share and month.

Table B.3 presents test results of regression (11). The coefficient loading of $\Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t)$ is of our interest, which measures the difference in outflow-rate sensitivity (bond fund fragility) under low v.s. high Fed fund rate regimes. Significantly positive coefficients in all specifications suggest that sensitivity of investors' redemption rises as Fed funds target rate increases in a lower Fed fund rate regime. In particular, during contractionary monetary policy periods with high TFF rates, fund flows do not react to the change in TFF rate; while during expansionary periods with low TFF rates, a 1% increase in TFF is associated with 4.174% (=3.454% + 0.720%) incremental outflows, around 68.48 Billion USD outflows benchmarked to the total size of corporate bond mutual funds in 2017. These results are consistent with the model prediction that bond funds become more fragile in a low Fed fund rate regime.

3.2.3 Bond fund fragility induced by monetary policy uncertainty

Hypothesis 3 predicts that in a relatively liquid market, the outflow-to-rate sensitivity is greater when monetary policy uncertainty is higher. We call this "bond fund fragility induced by high monetary policy uncertainty". We test this hypothesis using the same methodology as in Section 3.2.2 based on the following regression:

$$
\begin{aligned}
OutFlow_{i,t} = {} & \alpha_i * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) + \Delta TFF_t * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) + Controls^M_t * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) \\
& + Controls^F_{i,t} * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) + Controls^I_{i,t} * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) + \varepsilon_{i,t}, \quad \forall DFL_t < \overline{DFL_t},
\end{aligned} \tag{12}
$$

where $\mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t)$ is an indicator variable that equals one if MPU^{HRS} is above the top tercile and zero if it is below the the bottom tercile over the sample period (see Figure 3), and all other details are the same as in Equation (11).

Table B.4 presents the results of regression (12). It shows that the outflow-rate sensitivity is significantly stronger in the periods with high monetary policy uncertainty. In fact, outflow-rate relation overturns (insignificantly) when monetary policy uncertainty is low; while in higher uncertain periods, a 1% increase in TFF is associated with 2.675% (=3.613%-0.938%) incremental outflows, around 39.76 Billion USD outflows benchmarked to the total size of corporate bond mutual funds in 2017. This result is consistent with the model prediction that bond funds become more fragile in a higher monetary policy uncertainty regime.

3.2.4 Complementary effects of monetary policy looseness and uncertainty

Extending the findings that both looseness and uncertainty of monetary policy contribute to fund fragility, we further show they have complementary effects on bond mutual fund fragility, as predicted by Hypothesis 4. We adopt a three-way interaction panel regression to test this hypothesis:

(13)

$$OutFlow_{i,t} = \alpha_i * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) + \Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t)$$
$$+ Controls_t^M * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) + Controls_{i,t}^F * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t)$$
$$+ Controls_{i,t}^I * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t) + \varepsilon_{i,t}.$$

The regression results are shown in Table B.5. The positive coefficients of $\Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{MPU}^{HRS}{}_t)$ indicate that the outflows-rate sensitivity (fund fragility) is highest in the periods when Fed funds target rate is low and monetary policy uncertainty is high. In these months, a 1% increase in TFF is associated with 3.735% (=13.508%-12.099%-9.394%+11.720%) incremental outflows, three times higher than the average effect (1.077%) reported in Table B.2.

In a nutshell, above three sets of results demonstrate the important role of monetary policy in determining bond mutual fund fragility. These results raise the concerns for unexpected consequences of monetary policy on the bond mutual fund industry.

3.2.5 The effect of illiquidity on the monetary-policy-induced fragility

Next, we study how bond market illiquidity affects monetary policy induced fragility. The insight given by Goldstein, Jiang, and Ng (2017) suggests that illiquidity intensifies strategic complementarities among redemption decisions for bond fund investors. In our model, illiquidity has a second effect that attenuates fragility induced by monetary policy looseness and uncertainty, as shown in Hypothesis 5. These predictions are verified using three-way interaction regressions:

$$(14)\qquad OutFlow_{i,t} = \alpha_i * \mathbb{1}(MP_t) * \mathbb{1}(\text{High}^t\ \text{Illiq}_t) + \Delta TFF_t * \mathbb{1}(MP_t) * \mathbb{1}(\text{High}^t\ \text{Illiq}_t)$$
$$+ Controls_t^M * \mathbb{1}(MP_t) * \mathbb{1}(\text{High}^t\ \text{Illiq}_t) + Controls_{i,t}^F * \mathbb{1}(MP_t) * \mathbb{1}(\text{High}^t\ \text{Illiq}_t)$$
$$+ Controls_{i,t}^I * \mathbb{1}(MP_t) * \mathbb{1}(\text{High}^t\ \text{Illiq}_t) + \varepsilon_{i,t},$$

where MP_t represents either monetary policy looseness $\text{Low}^t\ \text{TFF}_t$ or monetary policy uncertainty $\text{High}^t\ \text{MPU}^{HRS}{}_t$, and $\mathbb{1}(\text{High}^t\ \text{Illiq}_t)$ is an indicator variable that equals one if market illiquidity measure is above the top tercile and zero if it is below the bottom tercile over the sample period[13], and all other details are the same as in Equation (11), and all other details are the same as in Equation (11). We adopt three proxies for market illiquidity – VIX index, DFL index by Dick-Nielsen, Feldhütter, and Lando (2012) and TED rate.

Table B.6 and B.7 shows the results. As predicted, the coefficient loadings for $\Delta TFF_t * \mathbb{1}(MP_t) * \mathbb{1}(\text{High}^t\ \text{Illiq}_t)$ are all significantly negative, indicating that bond market illiquidity weakens fragility induced by monetary policy looseness and uncertainty. The economic effects are huge. For example, in months with higher VIX and lower Fed funds target rate, the change in TFF is not associated with outflow at all (a 1% increase in TFF is linked with -0.148% (=-5.254%+2.259%+1.899%+0.948%) incremental outflows); while the average effect in low Fed funds rate regime is 4.174% as reported in Table B.3. Therefore, the market illiquidity totally wipes out fragility induced by monetary policy looseness. Similarly, in months with higher VIX and higher monetary policy uncertainty, a 1% increase in TFF is associated with 0.841% (=-5.725%+4.482%+4.886%-2.802%) incremental outflows, significantly smaller than the average effect of 2.675% reported in Table B.4.

[13] As TED rate and Fed funds target rate is correlated, regression with $\mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{TED}_t)$ has collinearity problem. Therefore, I replace $\mathbb{1}(\text{High}^t)\ \text{TED}_t$ by $\mathbb{1}(\text{High}^m\ \text{TED}_t)$ where $\mathbb{1}(\text{High}^m\ \text{TED}_t)$ equals one if TED is above the sample mean and zero if it is below the sample mean over the sample period

4 Conclusion

This paper studies how the looseness and uncertainty in monetary policy affects fragility in the corporate bond mutual fund sector. We argue that accommodative and uncertain monetary policy can exacerbate the bond fund fragility. We establish this result through a model of runs on bond funds. The empirical analysis of corporate bond mutual funds over the January 1992 to December 2017 confirms the predictions of the model. A key takeaway from this paper is that when deciding monetary policy, policymakers need to consider its impacts on the fragility of the financial market.

Appendix

A Figures

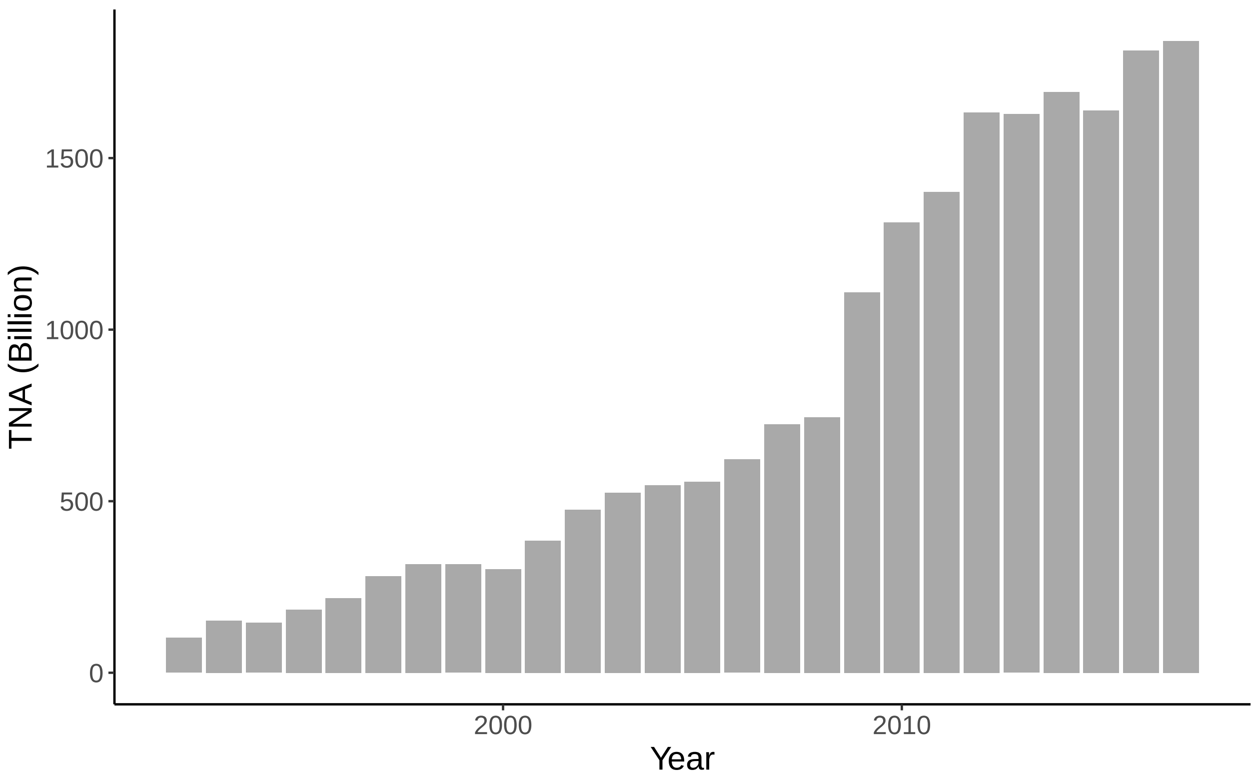

Figure 1: Total net asset of corporate bond mutual funds. This figure shows total net assets (TNA) and dollar flows of managed corporate bond mutual funds from January 1992 to December 2017. We exclude index corporate bond mutual funds, exchange traded funds, and exchange traded notes from the CRSP mutual fund database.

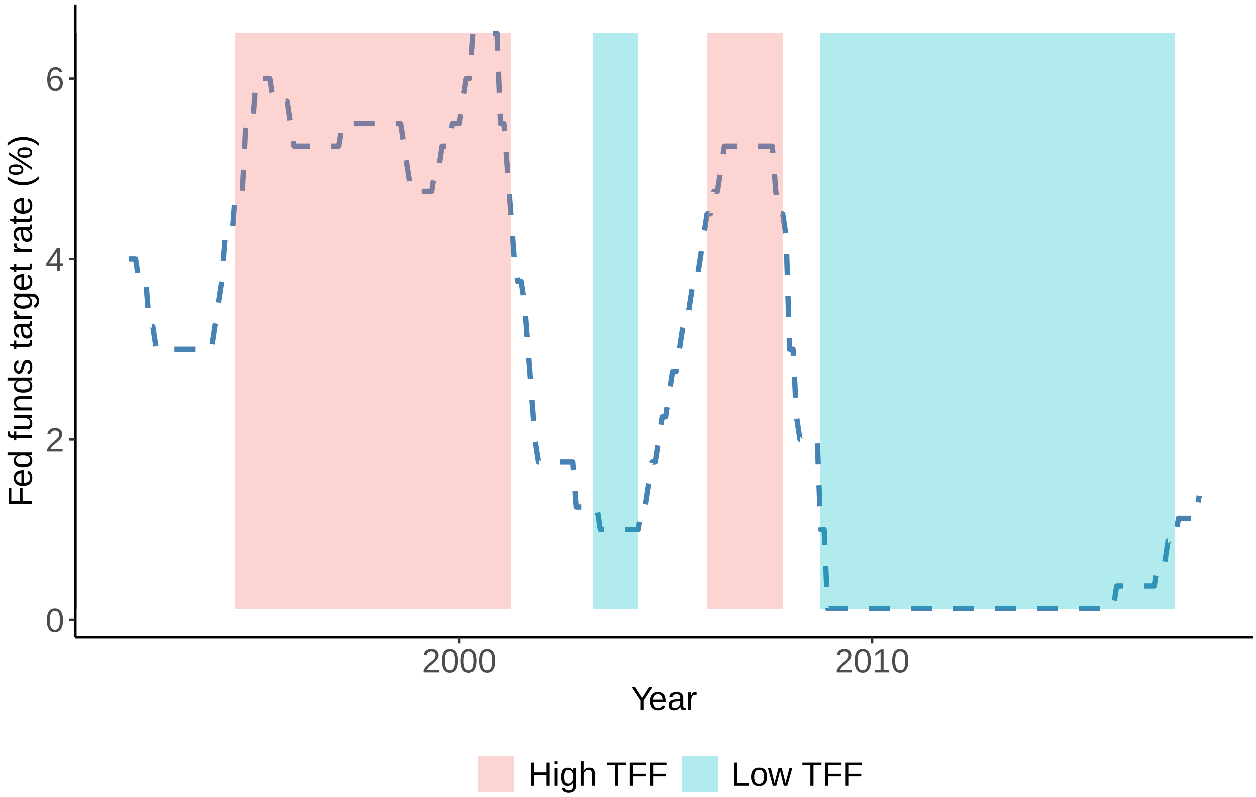

Figure 2: Plot of Fed funds target rate and high and low Fed fund rate regimes. This figure plots the Fed funds target rate (TFF) from January 1992 to December 2017. The low (high) Fed fund rate regime corresponds to the periods when the Fed funds target rate is below (above) the bottom (top) tercile.

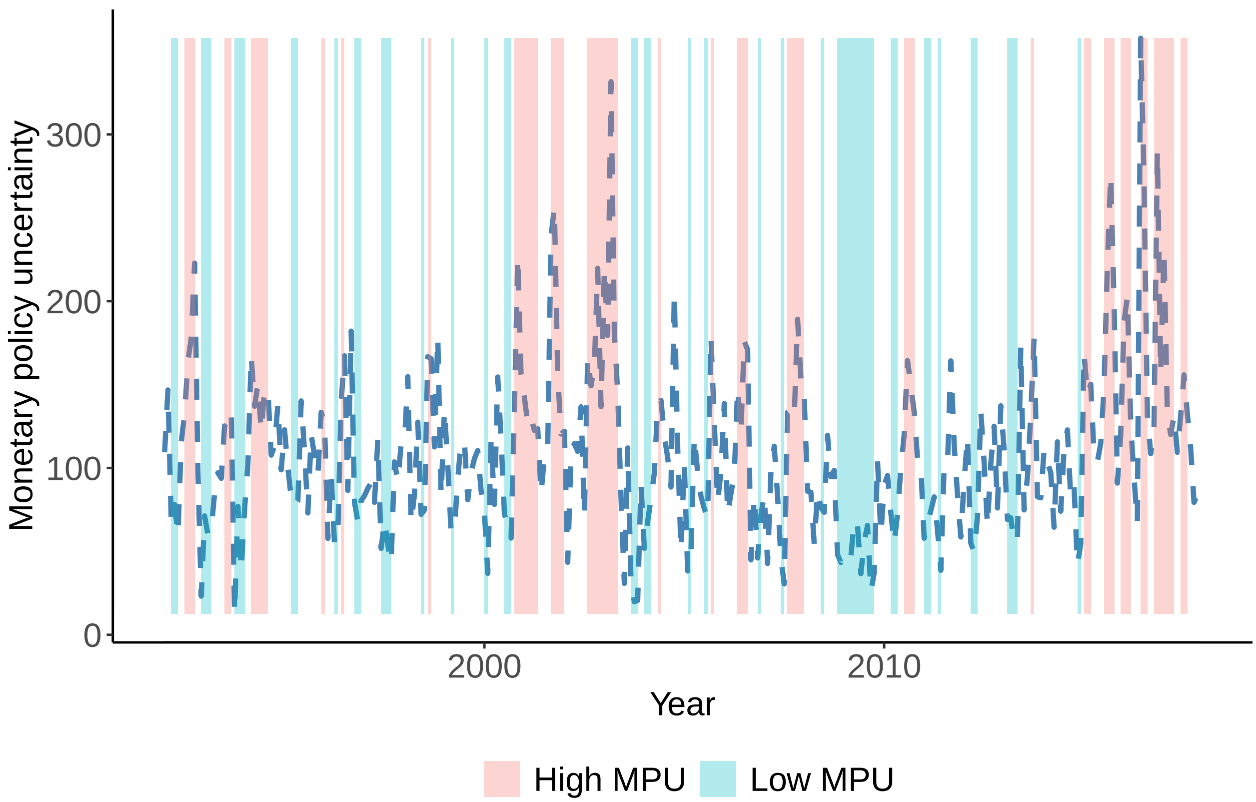

Figure 3: Plot of monetary policy uncertainty index and high and low Fed fund rate regimes. There figures plot monthly monetary policy uncertainty index constructed by Husted, Rogers, and Sun (2017). "MPU HRS" is constructed based on keywords related to monetary policy uncertainty in the New York Times, Wall Street Journal and Washington Post. The high (low) monetary policy uncertainty regime corresponds to the periods when the monetary policy uncertainty index is above (below) the top (bottom) tercile.

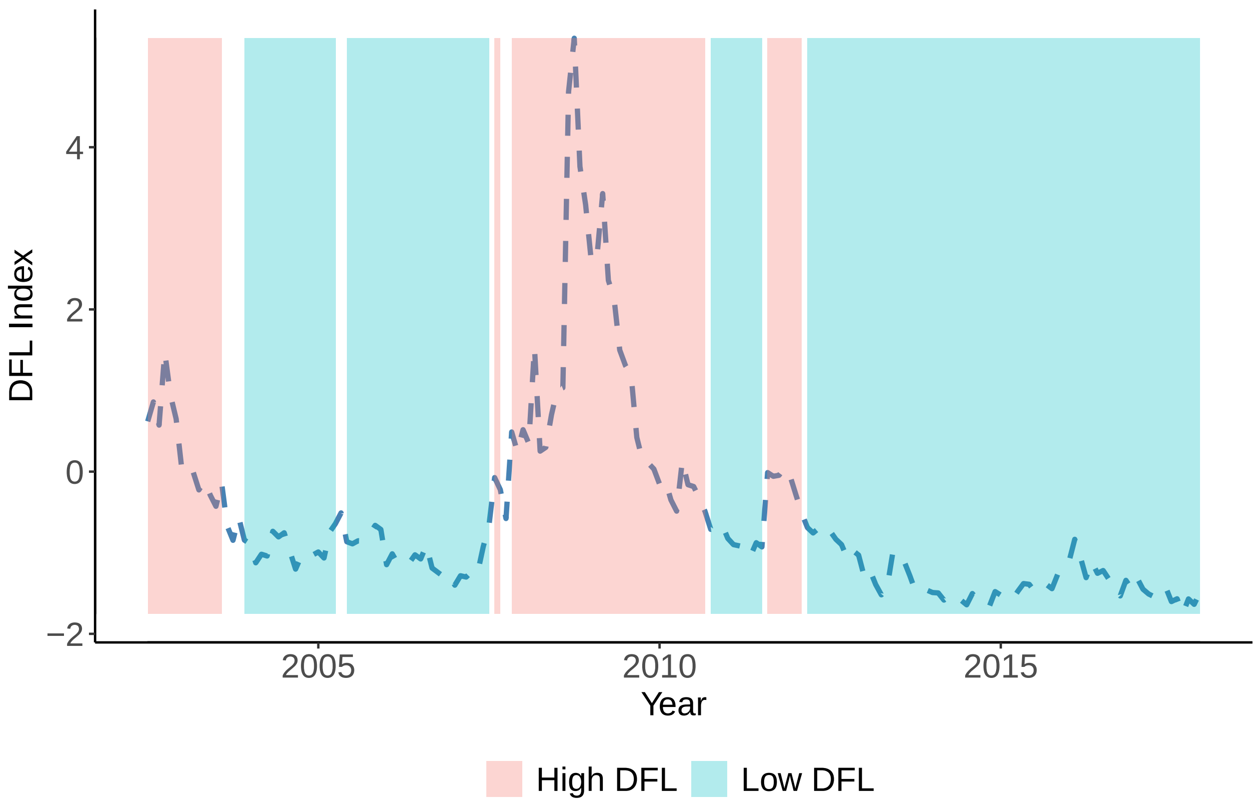

Figure 4: Plot of VIX index and high and low bond market illiquidity regimes. This figure plots the DFL index constructed by Dick-Nielsen, Feldhütter, and Lando (2012) from July 2002 to December 2017. The high (low) market illiquidity regime corresponds to the periods when the DFL index is above (below) the sample mean.

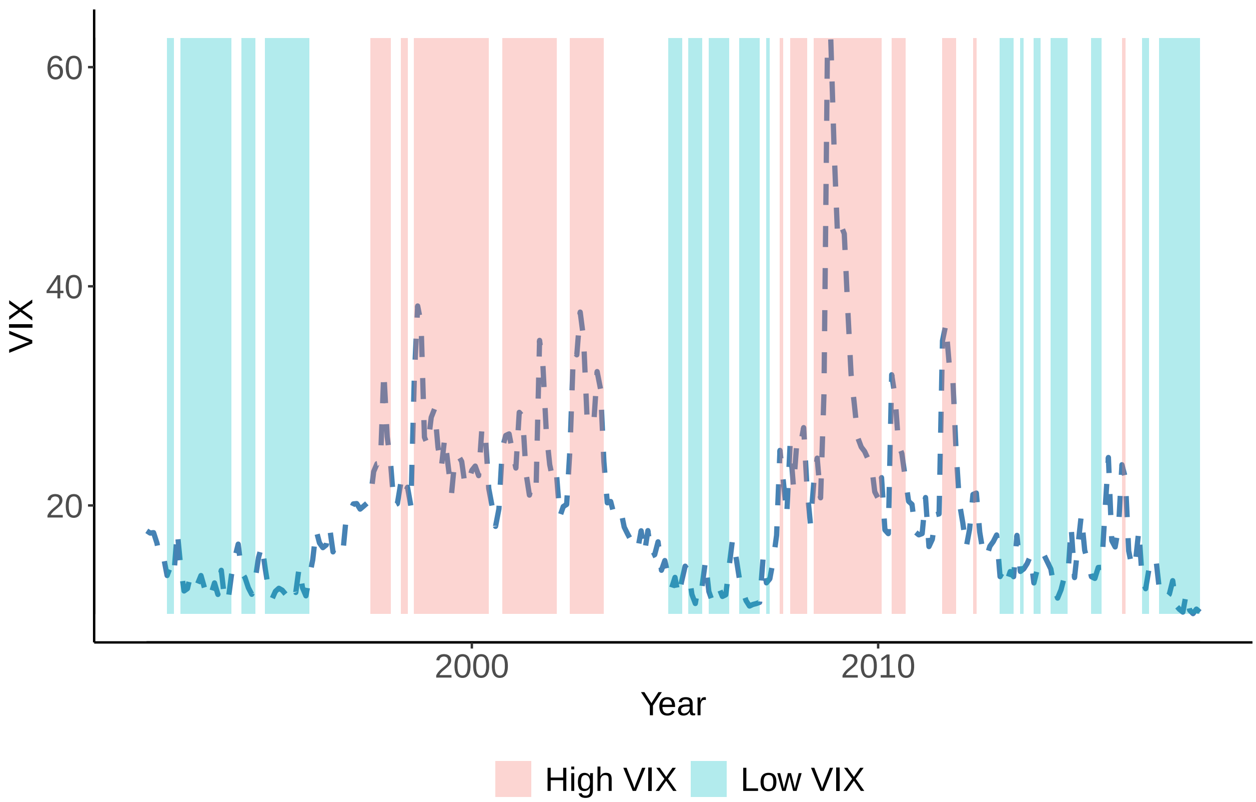

Figure 5: Plot of VIX index and high and low bond market illiquidity regimes. This figure plots the VIX index from January 1992 to December 2017. The high (low) market illiquidity regime corresponds to the periods when the VIX index is above (below) the top (bottom) tercile.

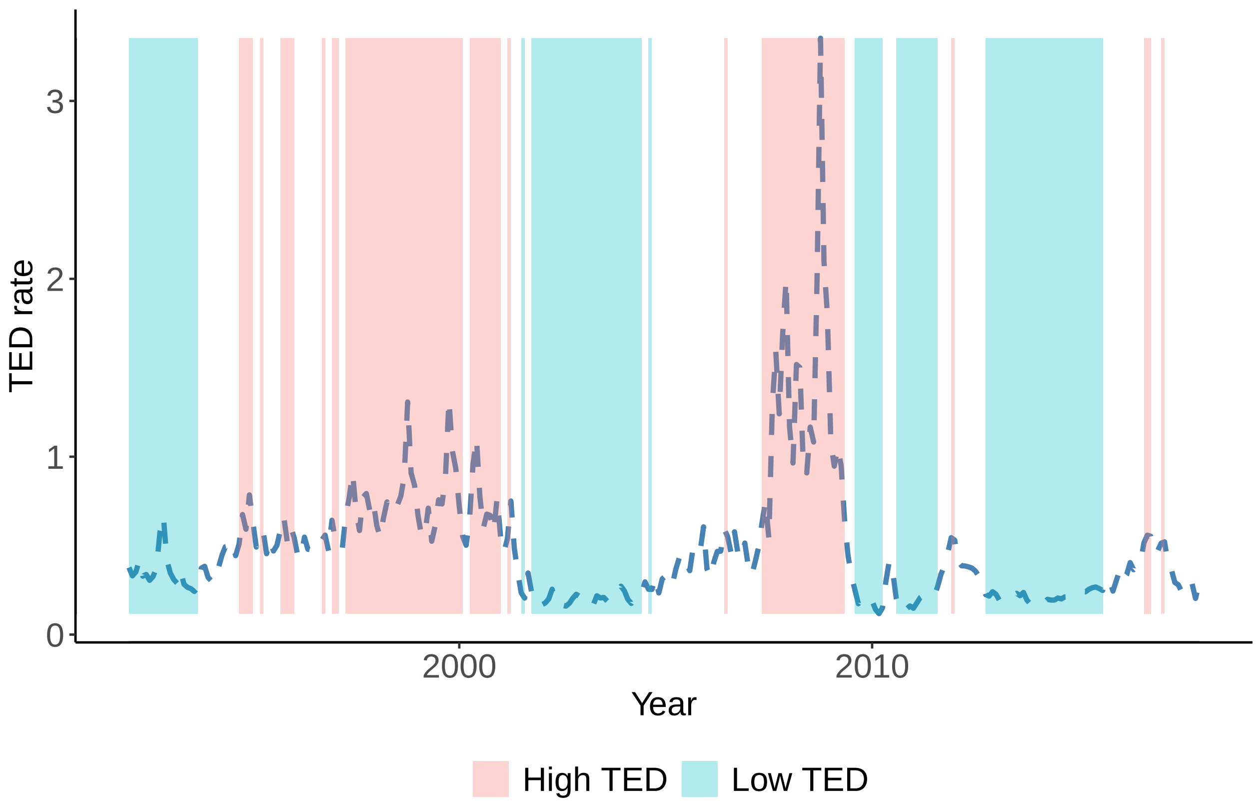

Figure 6: Plot of VIX index and high and low bond market illiquidity regimes. This figure plots the TED rate from January 1992 to December 2017. The high (low) market illiquidity regime corresponds to the periods when the TED rate is above (below) the top (bottom) tercile.

B Tables

	Mean	Std Dev	P5	P25	Median	P75	P95	N
Flow (%)	1.026	8.363	-7.380	-1.620	-0.129	1.951	14.028	530,768
Return (%)	0.401	1.353	-1.899	-0.164	0.388	1.070	2.499	530,768
Log(TNA)	3.665	2.521	-1.204	2.128	3.930	5.442	7.424	530,768
Log(Age)	1.783	0.993	-0.092	1.178	1.925	2.532	3.155	530,768
Expense (%)	1.031	0.488	0.370	0.660	0.920	1.410	1.900	475,413
Perf (%)	-0.027	0.456	-0.744	-0.262	-0.035	0.176	0.780	477,659
η_B	0.586	0.516	-0.125	0.271	0.576	0.872	1.445	477,659
η_M	0.114	0.164	-0.077	-0.001	0.059	0.205	0.443	477,659

Table B.1: Summary statistics of fund characteristics. This table presents the summary statistics for characteristics of all corporate bond mutual funds in our sample from January 1992 to December 2017. Flow (%) is the percentage fund flow in a given month, Fund return (%) is the monthly net fund return in percentage point, Log(TNA) is the natural log of total net assets (TNA), Log(Age) is the natural log of fund age in years since its inception in the CRSP database, Expense (%) is fund expense ratio in percentage point, Perf, η_B, η_M are coefficients from regression (9) for the funds. The unit of observations is fund share-month. The sample includes 5228 unique fund share classes and 1853 unique funds. We exclude index corporate bond mutual funds, exchange traded funds, and exchange traded notes from the CRSP mutual fund database.

	Dependent variable: $OutFlow_{i,t}$(%)					
	Full sample			Months with FOMC meetings		
	(1)	(2)	(3)	(4)	(5)	(6)
ΔTFF_t	1.724	1.107	0.986	1.731	1.233	1.077
	3.193***	3.575***	2.976***	3.179***	3.543***	2.954***
ΔYield slope$_t$		−0.123	−0.203		−0.100	−0.222
		−0.465	−0.684		−0.291	−0.597
ΔDefault spread$_t$		1.048	1.071		1.386	1.347
		2.624***	2.502**		2.795***	2.534**
ΔVIX$_t$		1.207	1.263		1.153	1.214
		3.361***	3.229***		2.965***	2.901***
$\mathbb{1}$(High^m VIX$_t$)		−0.890	−1.194		−0.768	−1.085
		−7.389***	−8.670***		−5.387***	−6.707***
$\mathbb{1}$(High^m MPU$_t^{HRS}$)		−0.150	0.052		−0.112	0.100
		−1.567	0.463		−0.952	0.723
$Perf_{i,t-1}$		−86.128	−49.120		−76.090	−38.493
		−6.604***	−3.625***		−5.210***	−2.482**
$R_{i,t-1}$		−25.948	−26.904		−25.728	−27.498
		−7.429***	−7.090***		−6.066***	−5.913***
Log(TNA$_{i,t}$)		0.039	0.053		0.038	0.063
		3.246***	1.349		2.818***	1.458
Expense$_{i,t}$		56.439	−181.390		51.398	−185.468
		6.610***	−5.631***		5.252***	−5.210***
Constant		−0.755			−0.756	
		−6.082***			−5.091***	
Fund FE	Y	N	Y	Y	N	Y
Observations	530,768	445,407	445,407	372,088	311,931	311,931
Adjusted R^2	0.050	0.010	0.055	0.050	0.010	0.055

Table B.2: Change in target fed fund rate drives fund flows, This table reports test for the effect of the change in monetary policy on fund flows to corporate bond mutual funds from January 1992 to December 2017. The dependent variable is $OutFlow_{i,t}$, which is the negative flow for fund i at month t. ΔTFF_t is the changes in the Fed funds target rate in percentage point. Fund characteristics include past performance (perf), past return, the natural log of total net asset, and expense ratios. All the variables are defined in section 3. Coefficients of the regression are reported in the shaded rows, and t-statistics are reported in the unshaded rows. Standard errors are clustered at fund share level. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

	Dependent variable: $OutFlow_{i,t}$(%)			
	Sample with Low^m DFL		Months with FOMC meetings & Low^m DFL	
	(1)	(2)	(3)	(4)
$\Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t)$	3.902	3.774	3.885	3.454
	3.385***	2.330**	3.038***	1.946*
ΔTFF_t	0.956	−0.056	1.182	0.720
	1.536	−0.147	1.524	1.389
ΔYield slope$_t$		0.325		1.658
		1.226		1.697*
ΔDefault spread$_t$		−4.653		−1.689
		−3.514***		−0.843
ΔVIX$_t$		1.469		0.149
		2.501**		0.261
$\mathbb{1}(\text{High}^m\ \text{MPU}_t^{HRS})$		0.174		0.455
		1.925*		3.840***
$Perf_{i,t-1}$		−175.212		−127.054
		−3.928***		−2.406**
$R_{i,t-1}$		−26.569		−16.843
		−2.434**		−1.264
Log(TNA$_{i,t}$)		−3.425		−3.327
		−5.024***		−3.658***
Expense$_{i,t}$		−42.560		−57.149
		−0.605		−0.720
Interactions	Y	Y	Y	Y
Fund FE	Y	Y	Y	Y
Observations	245,629	202,713	164,906	136,026
Adjusted R^2	0.116	0.112	0.113	0.109

Table B.3: Loose monetary policy induces fragility. This table reports test for fragility induced by loose monetary policy in a liquid market condition for corporate bond mutual funds. The market is liquid if the DFL index by Dick-Nielsen, Feldhütter, and Lando (2012) is below the average over 2002 to 2017. The dependent variable is $OutFlow_{i,t}$, which is the negative flow for fund i at month t. ΔTFF_t is the changes in the Fed funds target rate in percentage point. Low^t equals to one if the corresponding variable is below the bottom tercile and zero if it is above the top tercile over the sample period; the opposite for High^t. Fund characteristics include past performance (perf), past return, the natural log of total net asset, and expense ratios, defined in section 3. Interactions include all all the interaction terms with control variables and fixed effects. Coefficients of the regression are reported in the shaded rows, and t-statistics are reported in the unshaded rows. Standard errors are clustered at fund and month levels. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

	Dependent variable: $OutFlow_{i,t}(\%)$			
	Sample with Low^m DFL		Months with FOMC meetings & Low^m DFL	
	(1)	(2)	(3)	(4)
$\Delta TFF_t * \mathbb{1}(\text{High}^t\ \text{MPU}_t^{HRS})$	2.900	3.749	2.565	3.613
	2.101**	2.560**	1.602	2.191**
ΔTFF_t	−1.053	−1.585	−0.688	−0.938
	−0.960	−1.384	−0.535	−0.723
ΔYield slope$_t$		1.799		2.084
		3.220***		4.098***
ΔDefault spread$_t$		2.022		5.449
		1.268		2.697***
ΔVIX$_t$		1.719		1.319
		2.668***		1.724*
$\mathbb{1}(\text{Low}\ ^m\text{TFF}_t)$		1.213		1.351
		5.467***		4.443***
$Perf_{i,t-1}$		−180.793		−202.375
		−5.308***		−5.119***
$R_{i,t-1}$		−37.063		−31.945
		−4.630***		−3.032***
Log(TNA$_{i,t}$)		−0.193		−0.216
		−2.473**		−2.279**
Expense$_{i,t}$		−128.051		−148.215
		−2.395**		−2.291**
Interaction terms	Y	Y	Y	Y
Fund FE	Y	Y	Y	Y
Observations	200,109	167,334	134,954	112,585
Adjusted R^2	0.113	0.110	0.110	0.110

Table B.4: Monetary policy uncertainty induces fragility. This table reports test for fragility induced by monetary policy uncertainty in a liquid market for corporate bond mutual funds. The market is liquid if the DFL index by Dick-Nielsen, Feldhütter, and Lando (2012) is below the average over 2002 to 2017. MPU^{HRS} is the monthly MPU index developed by Husted, Rogers, and Sun (2017). Low^t equals to one if the corresponding variable is below the bottom tercile and zero if it is above the top tercile over the sample period; the opposite for High^t. All panel regressions include fund share fixed effect to control for flows to individual fund due to specific reasons. Interactions include all all the interaction terms with control variables and fixed effects. Coefficients of the regression are reported in the shaded rows, and t-statistics are reported in the unshaded rows. Standard errors are clustered at fund and month levels. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

	Dependent variable: $OutFlow_{i,t}$(%)			
	Full Sample		Months with FOMC meetings	
	(1)	(2)	(3)	(4)
$\Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(\text{High}^t\ \text{MPU}_t^{HRS})$	9.183	6.335	13.435	13.508
	3.180***	2.045**	3.777***	3.340***
$\Delta TFF_t : \mathbb{1}(\text{Low}^t\ \text{TFF}_t)$	−7.142	−5.094	−11.029	−12.099
	−2.761***	−1.714*	−3.367***	−3.222***
$\Delta TFF_t * \mathbb{1}(\text{High}^t\ \text{MPU}_t^{HRS})$	−5.362	−3.254	−9.190	−9.394
	−2.010**	−1.163	−2.753***	−2.612***
ΔTFF_t	7.322	4.909	11.197	11.720
	2.841***	1.690*	3.430***	3.329***
$\Delta\text{Yield slop}_t$		0.695		2.610
		0.829		1.258
$\Delta\text{Default spread}_t$		−0.524		14.626
		−0.193		1.764*
ΔVIX_t		1.233		−2.945
		1.095		−1.286
$\mathbb{1}(\text{High}\ ^m\text{VIX}_t)$		−0.757		−1.402
		−1.923*		−2.573**
$Perf_{i,t-1}$		−196.818		−94.604
		−4.660***		−1.772*
$R_{i,t-1}$		−15.540		−18.162
		−1.401		−1.277
$\text{Log}(\text{TNA}_{i,t})$		0.183		0.247
		1.432		1.426
$\text{Expense}_{i,t}$		2.484		−20.046
		0.043		−0.345
Interaction terms	Y	Y	Y	Y
Fund FE	Y	Y	Y	Y
Observations	278,815	230,885	192,223	158,741
Adjusted R^2	0.113	0.112	0.114	0.114

Table B.5: Complementary effects of monetary policy looseness and uncertainty. This table reports test for complementary effect of monetary policy looseness and uncertainty on fragility for corporate bond mutual funds from January 1992 to December 2017. MPU^{HRS} is the monthly MPU index developed by Husted, Rogers, and Sun (2017). Low^t equals to one if the corresponding variable is below the bottom tercile and zero if it is above the top tercile over the sample period; the opposite for High^t. Other variables are defined in Table B.2. All panel regressions include fund share fixed effect to control for flows to individual fund due to specific reasons. Interactions include all all the interaction terms with control variables and fixed effects. Coefficients of the regression are reported in the shaded rows, and t-statistics are reported in the unshaded rows. Standard errors are clustered at fund and month levels. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

$\mathbb{1}(Illiq_t)$	Full Sample High^t VIX (1)	Full Sample High^m TED (2)	Full Sample High^t DFL (3)	Months with FOMC meetings High^t VIX (4)	Months with FOMC meetings High^m TED (5)	Months with FOMC meetings High^t DFL (6)
	Dependent variable: $OutFlow_{i,t}(\%)$					
$\Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t) * \mathbb{1}(Illiq_t)$	−4.234	−6.905	−3.044	−5.254	−6.563	−5.219
	−1.802*	−3.141***	−3.127***	−2.379**	−2.156**	−3.394***
$\Delta TFF_t * \mathbb{1}(\text{Low}^t\ \text{TFF}_t)$	1.949	3.820		2.259	2.622	
	0.952	2.217**		1.236	1.053	
$\Delta TFF_t * \mathbb{1}(Illiq_t)$	1.896	0.038	0.203	1.899	−1.421	1.720
	1.343	0.032	0.134	1.272	−0.679	0.907
ΔTFF_t	0.743	1.785	3.467	0.948	3.218	3.801
	0.747	1.906*	2.683***	0.820	1.641	2.728***
ΔYield slop_t	−0.545	−0.527	3.024	−1.290	3.576	6.889
	−0.989	−0.584	2.976***	−1.947*	2.415**	3.518***
ΔDefault spread_t	−5.529	−7.309	−9.440	−1.466	−1.314	−10.051
	−1.943*	−1.972**	−5.517***	−0.289	−0.214	−2.122**
ΔVIX_t	0.206	1.100	1.594	0.953	−0.326	1.517
	0.174	0.834	2.160**	0.657	−0.271	1.102
$\mathbb{1}(\text{High}^m\ \text{MPU}_t^{HRS})$	0.048	−0.095	−0.347	0.078	0.352	0.503
	0.249	−0.281	−1.500	0.334	1.426	2.052**
$Perf_{i,t-1}$	−39.417	−113.636	−118.965	−18.888	−62.669	−46.443
	−0.900	−2.202**	−1.203	−0.404	−0.793	−0.336
$R_{i,t-1}$	−26.128	−32.274	−10.869	−16.466	20.213	−14.758
	−3.088***	−1.445	−0.925	−1.618	1.400	−0.934
$\text{Log}(\text{TNA}_{i,t})$	−0.195	−0.034	−7.274	−0.028	−0.153	−5.781
	−0.806	−0.116	−3.485***	−0.109	−0.347	−2.614***
$\text{Expense}_{i,t}$	−73.268	81.059	−77.372	−94.388	74.133	11.666
	−0.698	0.803	−0.626	−0.852	0.595	0.051
Interaction terms	Y	Y	Y	Y	Y	Y
Fund FE	Y	Y	Y	Y	Y	Y
Observations	208,665	338,396	188,602	145,222	232,592	130,429
Adjusted R^2	0.144	0.111	0.146	0.143	0.114	0.145

Table B.6: Market illiquidity weakens looseness-induced fragility. This table reports test for the effect of market illiquidity on looseness-induced fragility for corporate bond mutual funds from January 1992 to December 2017. VIX_t, TED_t and DFL_t are monthly VIX index and bond market illiquid index developed by Dick-Nielsen, Feldhütter, and Lando (2012). High^m (High^t) equals to one if the corresponding variable is above the average (in the top tercile) and zero if it is below the average (in the bottom tercile) over the sample period. Other variables are defined in Table B.2. All panel regressions include fund share fixed effect to control for flows to individual fund due to specific reasons. Interactions include all all the interaction terms with control variables and fixed effects. Coefficients of the regression are reported in the shaded rows, and t-statistics are reported in the unshaded rows. Standard errors are clustered at fund and month levels. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

	Dependent variable: $OutFlow_{i,t}(\%)$					
	Full Sample			Months with FOMC meetings		
$\mathbb{1}(Illiq_{i,t})$	High^t VIX	High^t TED	High^t DFL	High^t VIX	High^t TED	High^t DFL
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta TFF_t * \mathbb{1}(\text{Hign}^t\ \text{MPU}_t^{HRS}) * \mathbb{1}(Illiq_t)$	−4.354	−5.515	−2.185	−5.725	−7.497	−2.917
	−2.289**	−1.672*	−1.963**	−2.192**	−2.312**	−2.208**
$\Delta TFF_t * \mathbb{1}(Illiq_t)$	2.815	3.453		4.482	5.564	
	1.758*	1.192		1.811*	1.962**	
$\Delta TFF_t * \mathbb{1}(\text{Hign}^t\ \text{MPU}_t^{HRS})$	3.394	6.039	1.796	4.886	7.905	1.484
	2.151**	1.980**	1.160	2.211**	2.828***	0.850
ΔTFF_t	−1.093	−2.943	1.167	−2.802	−4.945	2.115
	−0.818	−1.091	1.067	−1.349	−2.165**	1.796*
$\Delta\text{Yield slop}_t$	1.591	0.125	2.037	−2.478	−0.346	2.828
	1.951*	0.089	3.588***	−2.201**	−0.276	3.511***
$\Delta\text{Yield slop}_t$	4.733	1.292	1.111	13.113	5.268	2.197
	1.849*	0.507	0.644	2.782***	3.120***	0.799
ΔVIX_t	1.862	−0.633	2.635	1.030	1.199	1.727
	1.973**	−0.239	4.091***	0.676	0.725	0.653
$\mathbb{1}(\text{Low}^m\text{TFF}_t)$	1.277	−0.134	1.909	1.283	0.486	2.646
	4.924***	−0.154	5.965***	3.056***	0.793	6.657***
$Perf_{i,t-1}$	−146.429	−128.779	−263.949	−118.308	−178.749	−390.808
	−3.316***	−3.579***	−4.785***	−1.878*	−5.076***	−7.755***
$R_{i,t-1}$	−30.203	−39.635	−45.980	−22.517	−36.549	−35.267
	−3.237***	−4.080***	−2.244**	−1.398	−2.670***	−1.507
$\text{Log}(\text{TNA}_{i,t})$	−0.123	0.011	−0.490	−0.066	−0.118	−0.964
	−1.300	0.093	−2.129**	−0.545	−0.894	−1.417
$\text{Expense}_{i,t}$	−47.027	−252.727	−137.221	−74.429	−260.091	−114.327
	−0.876	−3.893***	−1.272	−1.158	−3.115***	−0.740
Interaction terms	Y	Y	Y	Y	Y	Y
Fund FE	Y	Y	Y	Y	Y	Y
Observations	196,235	203,615	156,712	140,636	146,103	107,797
Adjusted R^2	0.145	0.125	0.167	0.145	0.130	0.164

Table B.7: Market illiquidity weakens uncertainty-induced fragility. This table reports test for the effect of market illiquidity on monetary uncertain-induced fragility for corporate bond mutual funds from January 1992 to December 2017. Low^t equals to one if the corresponding variable is below the bottom tercile and zero if it is above the top tercile over the sample period; the opposite for High^t. Other variables are defined in Table B.2. All panel regressions include fund share fixed effect to control for flows to individual fund due to specific reasons. Interactions include all all the interaction terms with control variables and fixed effects. Coefficients of the regression are reported in the shaded rows, and t-statistics are reported in the unshaded rows. Standard errors are clustered at fund and month levels. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

C Proofs

C.1 Lemma 1

Proof. In the liquid region $\lambda \leq \frac{\mathcal{L}p_1}{\bar{p}_1}$, the derivative of $\Delta\pi(\lambda)$ with respect with λ in Equation (4) is

$$\frac{\partial \Delta\pi(\lambda)}{\partial \lambda} = \frac{1}{p_0} \frac{\bar{p}_1 - p_1 \mathcal{L}}{p_1 \mathcal{L}(1-\lambda)^2} \geq 0.$$

The last inequality comes from the restriction that $\mathcal{L} \leq \frac{\bar{p}_1}{p_1} \leq 1$ in the intermediate region. In the illiquid region, the derivative of $\Delta\pi(\lambda)$ with respect with λ in Equation (4) is

$$\frac{\partial \Delta\pi(\lambda)}{\partial \lambda} = -\frac{1}{p_1} \frac{\mathcal{L}}{\lambda^2} \leq 0.$$

Moreover,

$$\Delta\pi(0) = \frac{1}{p_0}\left(\frac{\bar{p}_1}{p_1} - 1\right) < 0$$
$$\Delta\pi\left(\frac{\mathcal{L}p_1}{\bar{p}_1}\right) = \frac{1}{p_0}\frac{\bar{p}_1}{p_1} > 0$$
$$\Delta\pi(1) = \frac{1}{p_0}\frac{\mathcal{L}}{(1)} > 0$$

Therefore, there exist and only exist one $\hat{\lambda}$ such that $\Delta\pi(\hat{\lambda}) = 0$, and $\Delta\pi(\lambda) < 0$ when $\lambda < \hat{\lambda}$ and $\Delta\pi(\lambda) > 0$ when $\lambda > \hat{\lambda}$.

□

C.2 Proposition 1

Proof. This proof applied the standard global results in Goldstein and Pauzner (2005). The proof contains three steps. First, we proof there is a unique symmetric switching strategy, in which every investor redeems when $v > v^*$ and stays when $v < v^*$. Second, we show λ given v^* is uniformly distributed. Last, we solve the equilibrium threshold v^*.

Step 1 The net payoff $\Delta\pi(\lambda, v)$ has the function form:

$$\Delta\pi(\lambda, v) = \begin{cases} \frac{\bar{p}_1}{p_0}\frac{1}{p_1} - \frac{1}{p_0(1-\lambda)} \times \left(1 - \frac{\lambda\bar{p}_1}{\mathcal{L}p_1}\right) & \text{if } 0 \leq \lambda \leq \frac{\mathcal{L}p_1}{\bar{p}_1} \\ \frac{\mathcal{L}}{p_0\lambda} & \text{otherwise..} \end{cases}$$

This net payoff function has the following properties:

1) $\Delta\pi(\lambda, v)$ is continuous and non-increasing in $p_1 = \frac{1}{1+r+v}$ (non-decreasing in v) for all λ (state monotonicity).

2) There is a unique v^* solving $\int_0^1 \Delta\pi(\lambda, v)d\lambda = 0$ (strict Laplacian State Monotonicity).
3) Payoff function is continuous (continuity).
4) $\Delta\pi(\lambda, v)$ follows the single-crossing property: for each v, there exists a $\lambda^* \in (0, 1)$ such that $\Delta\pi(\lambda, v) > 0$ for all $\lambda > \lambda^*$ and $\Delta\pi(\lambda, v) < 0$ for all $\lambda < \lambda^*$.
5) There are upper and lower dominance regions such that there exist sun-spot equilibria when $v \in [\underline{v}, \bar{v}]$.

Given all five properties of $\Delta\pi(\lambda, v)$, Lemma 2.3 in Morris and Shin (2001) concludes that there is a unique equilibrium and it is in symmetric switching strategy around a critical value v^*, such that investors redeem when $v > v^*$ and stays when $v < v^*$.

Step 2 We denote $f(v) = \sqrt{12}$ as the density function of v. Conditional on observing a realized signal v^*, v has the following distribution

$$F_{v|s_i}(v|s_i = v^*) = \frac{\int_{-\infty}^{v^*} f(v) f_\varepsilon(\frac{v^*-v}{\sigma_\varepsilon})dv}{\int_{-\infty}^{\infty} f(v) f_\varepsilon(\frac{v^*-v}{\sigma_\varepsilon})dv}.$$

Given the switching strategy defined in Proposition 1, the proportion of investors redeeming given receiving a signal $s^{'}$ equals to λ:

$$\lambda = Pr(s_i > v^*|s^{'}) = Pr(s^{'} + \sigma_\varepsilon \varepsilon > v^*|s^{'}) = 1 - F_\varepsilon(\frac{v^* - s^{'}}{\sigma_\varepsilon})$$
$$\Rightarrow \quad s^{'} = v^* - \sigma_\varepsilon F_\varepsilon^{-1}(1-\lambda)$$

We denote $G(\cdot|v^*)$ as the cumulative density function for λ given v^*. It can be derived by equaling the probability that a fraction less than λ and the probability that s is less than the $s^{'}$ defined above:

$$\begin{aligned}
G(\lambda|v^*) &= F_{v|s_i}\left(v^* - \sigma_\varepsilon F_\varepsilon^{-1}(1-\lambda)\middle|v^*\right) \\
&= \frac{\int_{-\infty}^{v^*-\sigma_\varepsilon F_\varepsilon^{-1}(1-\lambda)} f(v) f_\varepsilon(\frac{v^*-v}{\sigma_\varepsilon})dv}{\int_{-\infty}^{\infty} f(v) f_\varepsilon(\frac{v^*-v}{\sigma_\varepsilon})dv} \\
&= \frac{\int_{F_\varepsilon^{-1}(1-\lambda)}^{\infty} f(v^* - \sigma_\varepsilon z) f_\varepsilon(z)dz}{\int_{-\infty}^{\infty} f(v^* - \sigma_\varepsilon z) f_\varepsilon(z)dz} \qquad z = \frac{v^* - v}{\sigma_\varepsilon} \\
\lim_{\sigma_\varepsilon \to 0} G(\lambda|v^*) &= \frac{\int_{F_\varepsilon^{-1}(1-\lambda)}^{\infty} f(v^*) f_\varepsilon(z)dz}{\int_{-\infty}^{\infty} f(v^*) f_\varepsilon(z)dz} \\
&= 1 - F_\varepsilon\left(F_\varepsilon^{-1}(1-\lambda)\right) \\
&= \lambda
\end{aligned}$$

Therefore, the proportion of investors redeeming λ given switching threshold v^* is uniformly distributed over [0,1], that is, $f_{\lambda|v^*} = 1$.

Step 3 In the equilibrium, the marginal investor receiving signal v^* is indifference between investing in the fund and the bank, that is, $\int_\lambda \Delta\pi(\lambda) f_{\lambda|v^*} d\lambda = 0$. With above results, this equation can be written as

$$\underbrace{\int_0^{\frac{\mathcal{L}}{\bar{p}_1}\frac{1}{1+r+\sigma v^*}} \frac{\bar{p}_1}{p_0}(1+r+\sigma v^*) - \frac{1}{p_0(1-\lambda)} \times \left(1 - \frac{\lambda}{\mathcal{L}}\bar{p}_1(1+r+\sigma v^*)\right) d\lambda}_{\text{net payoff when the fund is liquid}} + \underbrace{\int_{\frac{\mathcal{L}}{\bar{p}_1}\frac{1}{1+r+\sigma v^*}}^1 \frac{\mathcal{L}}{p_0 \lambda} d\lambda}_{\text{net payoff when the fund is illiquid}} = 0.$$

Rearranging above equation gives

$$\frac{\mathcal{L}\left(\mathcal{L} + \mathcal{L}\log\left(\frac{\bar{p}_1(1+r+\sigma v^*)}{\mathcal{L}}\right) - 1\right) - \log(1 - \frac{\mathcal{L}}{\bar{p}_1(1+r+\sigma v^*)})\left(\bar{p}_1(1+r+\sigma s) - \mathcal{L}\right)}{\mathcal{L}p_0} = 0$$

Denote $X = \frac{1}{\bar{p}_1(1+r+\sigma v^*)}$, then the above condition can be written as

$$\mathcal{L}\left(\mathcal{L} + \mathcal{L}\log\left(\frac{1}{X\mathcal{L}}\right) - 1\right) - \left(\frac{1}{X} - \mathcal{L}\right)\log(1 - \mathcal{L}X) = 0. \tag{C.1}$$

Note that the solution for X in above equation is is a function of $\mathcal{L}$only. We denote $X = g(\mathcal{L})$. Rearrange above equation gives the expression (6).

Next, we summarize the properties of $g(\mathcal{L})$:

> **Lemma 2.** *Function $g(\mathcal{L})$ has the following properties: 1) $\frac{\partial g(\mathcal{L})}{\partial \mathcal{L}} < 0$; 2) $g(\mathcal{L})$ has a lower bound as 1; 3) $\lim_{\mathcal{L}\to 1} g(\mathcal{L}) = 1$.*

To prove above lemma, we first layout some useful inequalities (Topsok, 2006):

$$\frac{2z}{2+z} \geq log(1+z) \geq \frac{z}{2} \cdot \frac{2+z}{1+z} \quad \text{for } -1 < z \leq 0$$

$$log(1+z) \leq \frac{z}{2} \cdot \frac{6+z}{3+2z} \quad \text{for } z \geq 0.$$

We first show that there exist an solution to equation (C.1). It is clear that we have a condition that $\mathcal{L}X = \mathcal{L}g(\mathcal{L}) < 1$ such that $g(\mathcal{L}) < \frac{1}{\mathcal{L}}$. We define h function as below:

$$h_{\mathcal{L}}(X) = \mathcal{L}\left(\mathcal{L} - 1 + \mathcal{L}\log\left(\frac{1}{X\mathcal{L}}\right)\right) - \left(\frac{1}{X} - \mathcal{L}\right)\log(1 - \mathcal{L}X)$$

For each $\mathcal{L} \in [0, 1]$, we can show that

$$\lim_{X\to 1} h_{\mathcal{L}}(X) = \mathcal{L}\left(\mathcal{L} - 1 - \mathcal{L}\log(\mathcal{L})\right) - (1-\mathcal{L})\log(1-\mathcal{L}) > 0$$

$$\lim_{X\to\infty} h_{\mathcal{L}}(X) = \mathcal{L}\left(\mathcal{L} - 1 - \mathcal{L}\log(X\mathcal{L}) + \log(1 - \mathcal{L}X)\right) < \mathcal{L}\left(\mathcal{L} - 1 - \mathcal{L}\log(\mathcal{L}) + \log(1-\mathcal{L})\right) < 0$$

So for each $\mathcal{L}$, there exists at least one solution $X = g(\mathcal{L}) \in (1, \infty)$ such that $h_{\mathcal{L}}(X) = 0$.

Then, we take implicit derivative of function $X = g(\mathcal{L})$:

$$\frac{\partial g(\mathcal{L})}{\partial \mathcal{L}} = \frac{g(\mathcal{L})^2\Big(-\mathcal{L} - \log(1 - \mathcal{L}g(\mathcal{L})) - 2\mathcal{L}\log\Big(\frac{1}{\mathcal{L}g(\mathcal{L})}\Big)\Big)}{\mathcal{L}g(\mathcal{L})(-\mathcal{L}+1) + \log\Big(1 - \mathcal{L}g(\mathcal{L})\Big)}$$

The denominator of above derivative is negative since

$$\begin{aligned} & \mathcal{L}g(\mathcal{L})(-\mathcal{L}+1) + \log\Big(1 - \mathcal{L}g(\mathcal{L})\Big) \\ \leq \quad & \mathcal{L}g(\mathcal{L})(-\mathcal{L}+1) + (-\mathcal{L}g(\mathcal{L})) = -\mathcal{L}^2 g(\mathcal{L}) < 0 \end{aligned}$$

For the numerator of $\frac{\partial g(\mathcal{L})}{\partial \mathcal{L}}$, we have

$$\begin{aligned} & -\mathcal{L} - \log(1 - \mathcal{L}g(\mathcal{L})) + 2\mathcal{L}\log\Big(\mathcal{L}g(\mathcal{L})\Big) \\ & = -2 + \mathcal{L} + \Big(1 - \frac{2}{X\mathcal{L}}\Big)\log(1 - X\mathcal{L}) \qquad\qquad (\text{from } h_{\mathcal{L}}(X) = 0) \\ & \geq -2 + \mathcal{L} + \Big(1 - \frac{2}{X\mathcal{L}}\Big)\frac{2X\mathcal{L}}{2 - X\mathcal{L}} = \mathcal{L} \geq 0 \end{aligned}$$

Therefore, we have $\frac{\partial g(\mathcal{L})}{\partial \mathcal{L}} < 0$. Combining the existence of solution $g(\mathcal{L})$ in interval $(1, \infty)$, we can conclude that for each $\mathcal{L}$, there exists only one solution $g(\mathcal{L}) \in (1, \infty)$ such that $h_{\mathcal{L}}(g(\mathcal{L})) = 0$.

Lastly, we show $\lim_{\mathcal{L}\to 1} g(\mathcal{L}) = 1$. Suppose $X = g(\mathcal{L})$ converges some constant $\hat{g}$ as $\mathcal{L} \to 1$

$$\lim_{\mathcal{L}\to 1} h_{\mathcal{L}}(X) = 1 + \log\Big(\frac{1}{\hat{g}}\Big) - 1 - \Big(\frac{1}{\hat{g}} - 1\Big)\log(1 - \hat{g}) = 0.$$

As $\log(1 - \hat{g}) = -\sum_{n=1}^{\infty} \frac{\hat{g}^n}{n}$, we can rewrite the above equation as

$$\log\Big(\frac{1}{\hat{g}}\Big) + \Big(\frac{1}{\hat{g}} - 1\Big)\sum_{n=1}^{\infty}\frac{\hat{g}^n}{n} = \log\Big(\frac{1}{\hat{g}}\Big) + (1 - \hat{g})\sum_{n=1}^{\infty}\frac{\hat{g}^{n-1}}{n} = 0$$

If $\hat{g} < 1$, both terms are positive; if $\hat{g} > 1$, both terms are negative. Therefore, $\lim_{\mathcal{L}\to 1} g(\mathcal{L}) = \hat{g} = 1$.

□

C.3 Corollary 1

Proof. To start, we first lay out two results from Jensen's inequality:

$$\frac{1}{\bar{p}_1^2}\mathbb{E}\Big[\frac{1}{(1 + r + \sigma\tilde{v})^2}\Big] > 1,$$

$$(1 + r)\bar{p}_1 > 1.$$

Proof for a The partial derivatives of v^* on r is

$$\frac{\partial v^*}{\partial r} = \frac{1}{\sigma}\left(\frac{1}{g(\mathcal{L})}\frac{1}{\bar{p}_1^2}\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big] - 1\right)$$

$$\frac{\partial \mathbb{P}(v > v^*)}{\partial(-r)} = -f(v^*)\frac{\partial v^*}{\partial r}$$

When $g(\mathcal{L}) \to 1$, we have $\frac{\partial \mathbb{P}(v>v^*)}{\partial(-r)} > 0$, i.e., fund fragility is higher in the low interest rate regime.

Proof for b

$$\begin{aligned}
\frac{\partial v^*}{\partial \sigma} &= -\frac{1}{\sigma^2}\Big(\frac{1}{\bar{p}_1 g(\mathcal{L})} - (1+r) - \frac{1}{g(\mathcal{L})}\frac{1}{\bar{p}_1^2}\mathbb{E}\Big[\frac{\sigma\tilde{v}}{(1+r+\sigma\tilde{v})^2}\Big]\Big) \\
&= -\frac{1}{\sigma^2 g(\mathcal{L})\bar{p}_1}\Big(1 - (1+r)g(\mathcal{L})\bar{p}_1 - \frac{1}{\bar{p}_1}\mathbb{E}\Big[\frac{\sigma\tilde{v}}{(1+r+\sigma\tilde{v})^2}\Big]\Big) \\
&= \frac{1}{\sigma^2 g(\mathcal{L})\bar{p}_1^2}\Big((1+r)g(\mathcal{L})\bar{p}_1^2 - (1+r)\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\Big) \\
&= \frac{1+r}{\sigma^2}\Big(1 - \frac{1}{g(\mathcal{L})}\frac{1}{\bar{p}_1^2}\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\Big) \\
\frac{\partial \mathbb{P}(v > v^*)}{\partial \sigma} &= -f(v^*)\frac{\partial v^*}{\partial \sigma}
\end{aligned}$$

When $g(\mathcal{L}) \to 1$, we have $\frac{\partial \mathbb{P}(v>v^*)}{\partial \sigma} > 0$, i.e., fund fragility is higher in the high monetary policy uncertainty regime.

Moreover, there is a threshold $\tilde{\mathcal{L}}$ such that when $\mathcal{L} > \tilde{\mathcal{L}}$, $\frac{\partial \mathbb{P}(v>v^*)}{\partial(-r)} > 0$ and $\frac{\partial \mathbb{P}(v>v^*)}{\partial \sigma} > 0$. The $\tilde{\mathcal{L}} \in (0,1)$ is solution of the following equation:

$$g(\tilde{\mathcal{L}}) = \frac{1}{\bar{p}_1^2}\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big].$$

Proof for c The cross partial derivatives of v^* on r and σ, $\frac{\partial^2 v^*}{\partial r \partial \sigma}$ is positive

$$
\begin{aligned}
\frac{\partial^2 v^*}{\partial r \partial \sigma} =& \frac{1}{\sigma^2}\left(1 - \frac{1}{g(\mathcal{L})}\frac{1}{\bar{p}_1^2}\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\right) \\
&+ \frac{2}{\sigma g(\mathcal{L})\bar{p}_1^3}\left(\mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^2}\Big]\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big] - \mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^3}\Big]\bar{p}_1\right) \\
=& \frac{1}{\sigma^2 g(\mathcal{L})\bar{p}_1^3}\left(g(\mathcal{L})\bar{p}_1^3 - \mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\bar{p}_1 + 2\sigma\left(\mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^2}\Big]\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big] - \mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^3}\Big]\bar{p}_1\right)\right) \\
=& \frac{1}{\sigma^2 g(\mathcal{L})\bar{p}_1^3}\left(g(\mathcal{L})\bar{p}_1^3 - \mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\bar{p}_1 + 2\sigma\left(\mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^2}\Big]\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big] - \mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^3}\Big]\bar{p}_1\right)\right) \\
=& \frac{1}{\sigma^2 g(\mathcal{L})\bar{p}_1^4}\left(g(\mathcal{L})\bar{p}_1^4 - \mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\bar{p}_1^2 + 2(1+r)\bar{p}_1\left(\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^3}\Big]\bar{p}_1 - \mathbb{E}^2\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\right)\right) \\
\geq& \frac{1}{\sigma^2 g(\mathcal{L})\bar{p}_1^4}\left(\bar{p}_1^4 - \mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\bar{p}_1^2 + 2\left(\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^3}\Big]\bar{p}_1 - \mathbb{E}^2\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\right)\right) > 0
\end{aligned}
$$

The second last equality comes from the following derivation. Denote $Z = \frac{1}{1+r+\sigma\tilde{v}}$, we can derive

$$
\begin{aligned}
&\mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^2}\Big]\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big] - \mathbb{E}\Big[\frac{v}{(1+r+\sigma\tilde{v})^3}\Big]\bar{p}_1 \\
=& Cov\Big(\frac{v}{(1+r+\sigma\tilde{v})^3}, \frac{1}{(1+r+\sigma\tilde{v})}\Big) - Cov\Big(\frac{v}{(1+r+\sigma\tilde{v})^2}, \frac{1}{(1+r+\sigma\tilde{v})^2}\Big) \\
=& Cov\Big(\frac{1}{\sigma}\Big(\frac{1}{Z} - (1+r)\Big) \times Z^3, Z\Big) - Cov\Big(\frac{1}{\sigma}\Big(\frac{1}{Z} - (1+r)\Big) \times Z^2, Z^2\Big) \\
=& \frac{1+r}{\sigma}\Big(Cov(Z^2, Z^2) - Cov(Z^3, Z)\Big) \\
=& \frac{1+r}{\sigma}\Big(\mathbb{E}[Z^3]\mathbb{E}[Z] - \mathbb{E}[Z^2]\mathbb{E}[Z^2]\Big).
\end{aligned}
$$

The last inequality involves tedious calculation. We put the derivation in Mathmatica code online. Then we have

$$
\frac{\partial^2 \mathbb{P}(v > v^*)}{\partial(-r)\partial\sigma} = \underbrace{\frac{\partial f(v^*)}{\partial v^*}}_{=0}\underbrace{\frac{\partial v^*}{\partial \sigma}\frac{\partial v^*}{\partial r}}_{<0} + f(v^*)\underbrace{\frac{\partial^2 v^*}{\partial r \partial \sigma}}_{>0} > 0.
$$

Proof for d The cross partial derivatives of v^* on r and $\mathcal{L}$ is

$$
\frac{\partial^2 v^*}{\partial r \partial \mathcal{L}} = \frac{1}{\sigma}\frac{1}{g^2(\mathcal{L})}\frac{1}{\bar{p}_1^2}\mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big]\Big(-\frac{\partial g(\mathcal{L})}{\partial \mathcal{L}}\Big) > 0.
$$

Then we have

$$\frac{\partial^2 \mathbb{P}(v > v^*)}{\partial(-r)\partial(-\mathcal{L})} = -\underbrace{\frac{\partial f(v^*)}{\partial v^*}}_{=0} \underbrace{\frac{\partial v^*}{\partial \mathcal{L}}}_{>0} \frac{\partial v^*}{\partial r} - \underbrace{f(v^*)\frac{\partial^2 v^*}{\partial r \partial \mathcal{L}}}_{>0} < 0.$$

Similarly, the cross partial derivatives of v^* on σ and $\mathcal{L}$ is

$$\frac{\partial^2 v^*}{\partial \sigma \partial \mathcal{L}} = \frac{1+r}{\sigma^2} \frac{1}{g^2(\mathcal{L})} \frac{1}{\bar{p}_1^2} \mathbb{E}\Big[\frac{1}{(1+r+\sigma\tilde{v})^2}\Big] \frac{\partial g(\mathcal{L})}{\partial \mathcal{L}} < 0.$$

Then we have

$$\frac{\partial^2 \mathbb{P}(v > v^*)}{\partial \sigma \partial(-\mathcal{L})} = \underbrace{\frac{\partial f(v^*)}{\partial v^*}}_{=0} \underbrace{\frac{\partial v^*}{\partial \mathcal{L}}}_{>0} \frac{\partial v^*}{\partial \sigma} + \underbrace{f(v^*)\frac{\partial^2 v^*}{\partial \sigma \partial \mathcal{L}}}_{<0} < 0.$$

$\square$

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