Monetary Policy and Fragility in Corporate Bond Funds

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Abstract

We document aggregate outflows from corporate bond funds before the Federal Funds Target rate (FFTar) is increased. Our evidence supports a mechanism in which fund investors learn about the increase in FFTar and redeem their shares to profit from the temporary mispricing of net asset values (NAVs) arising from stale pricing and to avoid the liquidation cost from other investors' redemption. Consistent with the mechanism, we show that the sensitivity of outflow to increases in FFTar is greater when liquidity is lower. Stale NAVs and loose monetary policy environment increase (decrease) the sensitivity when liquidity is high (low). Our results highlight when and how monetary policy could systematically exacerbate the fragility in corporate bond funds.

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

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1 Introduction

Corporate bond mutual funds, as an asset class, have experienced dramatic growth since the financial crisis in 2008.[1] 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. In particular, existing research has documented disproportionate outflows in corporate bond funds following bad performances (Goldstein, Jiang, and Ng, 2017). This "runs on funds" phenomenon could in turn force the funds to liquidate their corporate bonds at a substantial discount, causing illiquidity spillovers to other asset markets. In this paper, we show that, on top of individual fund performance, outflows can also be triggered by macroeconomic news–the Federal Funds Target rate (FFTar) set by the Federal Reserve. Therefore, our mechanism points to aggregate outflows of corporate bond funds and potential systemic risks triggered by monetary policy.

The key force behind the outflow to changes in Federal Funds Target rate (outflow–ΔFFTar) relationship is the temporary stale pricing of fund shares before the Federal Open Market Committee (FOMC) meetings. Using daily data, we first show that increases in FFTar announced in the meetings are followed by decreases in the net-asset-value (NAV) of fund shares. Next, changes in FFTar are predictable days ahead by using information embedded in the Fed Funds futures or Eurodollar rates. Importantly, NAVs do not react immediately to information before the meetings and this stale pricing induces fund investors to redeem overpriced shares. NAVs are stale because their daily calculations are based on transaction prices of the corporate bonds, which might not reflect recent news since most bonds are traded less once a day.[2]

Figure 1 depicts our mechanism. In panel (a), the grey bar at date 0 was the FOMC meeting on December 18-19, 2018. In this meeting, a 25-basis-point increase in the FFTar (red) was

[1] 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 Securities Industry and Financial Markets Association (SIFMA).

[2] For instance, Friewald, Wagner, and Zechner (2014) show that from October 2004 to December 2008, the mean trading interval of corporate bonds is 4.46 days. The 5^{th} percentile is 1.5 days.

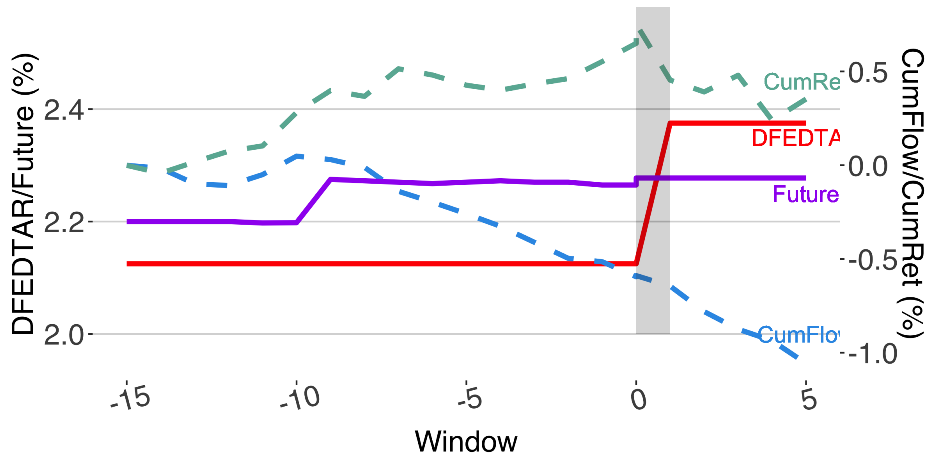

Figure 1: The time-series plot of the Federal Funds Target rate (in red), 30-day Federal Funds future (in purple), the cumulative return (in green) and the cumulative flow (in blue) of aggregate corporate bond funds around FOMC meeting on December 18-19, 2018.

announced. The average NAV (green) of corporate bond funds decreased subsequently. Yet, the market had predicted the policy rate change about 10 trading days before, as shown in the jump of the Fed Funds future (purple) and, notably, the NAV did not decrease on that date. Thus, the NAV was likely overpriced at that point and fund investors indeed started to redeem their shares, resulting in the outflow of funds (blue).

Outflows of corporate bond funds are also reinforced by the redemption externality among fund investors (Goldstein, Jiang, and Ng, 2017). Redeeming investors impose costs on staying investors because redemption forces fund managers to liquidate the assets, while the liquidation cost is only borne by staying investors. The externality increases in illiquidity, in the form of either fewer liquid assets held by funds or larger transaction costs of the corporate bonds.

To understand the distinct and joint effects of mispricing of NAV, due to staleness, and redemption externality, due to illiquidity, on fund flows in different monetary policy environments, in the

Appendix we build a model of strategic redemption by fund investors in the face of uncertain interest rate policy. In the model, upon receiving signals regarding future interest rate and hence bond values, fund investors choose between redeeming at the NAV and staying in the fund. In particular, investors redeem when the expected bond values are below certain threshold. The likelihood of such event represents the notion of fund fragility and is empirically proxied by the outflow–ΔFFTar relationship. The model captures two fundamental features of corporate bond funds, namely, the staleness in NAV due to infrequent trading of bonds and illiquidity of bonds. Our mechanism yields several testable hypotheses of which we found strong empirical support.

First, there is a positive relationship between outflows in funds and changes in FFTar. This is due to the mispricing of NAV. As increases in interest rate depress bonds and thus fund values, stale NAV implies that the NAV is temporarily overpriced. Hence, investors have incentives to redeem their shares before FOMC meetings if they can predict the future increases in FFTar. We test this prediction using daily flow data from MorningStar from January 2009 to December 2019. We first confirm in our sample that some FFTar changes are anticipated correctly by the market before the FOMC meetings, as shown in Cochrane and Piazzesi (2002): In 9 out of 12 meetings with changes in FFTar, the 30-day Federal Funds Future rates in a 10-day window before the meetings move in the same direction as the actual changes in FFTar.[3] Next, we show that for funds with high staleness, their NAVs do not move with information revealed by the Fed Futures before meetings but start to adjust in the opposite direction of the changes in FFTar changes after the meetings. This suggests that the NAVs are temporarily overpriced and investors indeed redeem before meetings. A 25-basis-point increase in FFTar is associated with a 0.17% increase in fund outflows in a 10-day window before FOMC meetings. Outflows are measured in the percentage of funds' total net asset values, and hence 0.17% outflows translate to 4.0 billion USD benchmarked to the total size of corporate bond mutual funds in 2019. In contrast, for funds with low staleness, we do not find the

[3] In the sample from January 1992 to December 2019, the sign of FFTar changes are correctly predicted by moves in ahead-of-meeting future rate changes in 54 meetings out of 75 meetings.

same flow pattern. Instead, their NAVs adjust with ahead-of-meeting Fed Future rates and, hence, relative to high-stale funds' NAVs, are likely to be less overpriced.

We further confirm the outflow–ΔFFTar relationship using monthly data with a longer sample period from January 1992 to December 2019. Quantitatively, a 25-basis-point increase in the FFTar, on average, is accompanied by 0.29% outflows in a month, roughly 6.8 billion USD benchmarked to bond funds' size in 2019. Moreover, the outflow-ΔFFTar relationship is asymmetric: greater in months with non-negative FFTar changes than in months with non-positive FFTar moves. This pattern is consistent with the redemption externality specifically related to outflow because outflow could force asset liquidation while inflow would not force asset purchase. During months with non-negative FFTar changes, we see 0.44% outflows for a 25-basis-point increase in the FFTar, 50% higher than the average case. The significant aggregate outflows in a short window could impose systemic risks on the corporate bond sector.

Second, illiquidity strengthens the outflow-ΔFFTar relationship because the redemption externality is more severe. For a given amount of redemption, an investor has to incur more liquidation costs if illiquidity is higher and therefore is more inclined to redeem, the same as in (Goldstein, Jiang, and Ng, 2017). Empirically, we see that investors withdraw 0.28% capital from *illiquid funds* in a 10-day window before meetings with potential increases in FFTar, while we do not find significant results for liquid funds.[4] Similarly, using monthly data, we confirm that the outflow–ΔFFTar relationship is significantly positive only in months with an illiquid market condition, measured by the VIX index, and in funds with less cash and government bond holdings. Take illiquid funds as an example: a 25-basis-point increase in the FFTar, on average, is accompanied by 0.67% outflows, an additional 50% increase, compared to the magnitude 0.44% for months with non-negative FFTar changes.

Third, when liquidity is high, staleness in NAV strengthens the outflow–ΔFFTar relationship. In

[4] For each FOMC meeting, we classify funds whose last year's percentage holding of liquid assets (cash and government bonds) is higher-(lower-)than-sample median as liquid (illiquid) funds.

this case, fund investors behave like arbitrageurs and they redeem when the shares are overpriced. Staler NAV, by definition, reflects less the updated bond values. As bond values drop after an interest rate increases, a staler NAV implies a larger NAV mispricing, inducing fund investors to redeem. In contrast, when liquidity is low, fund investors are primarily concerned with the redemption externality and thus might redeem even if the bond values remain high. In that case, staleness exacerbates little or could even reduce outflows. Both predictions are confirmed by data. Focusing on daily data, we compare the outflow–ΔFFTar relationship between high v.s. low stale funds for sub-samples of liquid and illiquid funds, separately. Within liquid funds, we show that only high-stale funds exhibit significant outflows prior to FOMC meetings with potentially positive FFTar updates. On the contrary, within illiquid funds, we see large outflows for *low-stale* funds before meetings: a 25-basis-point increase in FFTar is associated with a 0.45% increase in fund outflows in a 10-day window before FOMC meetings. This magnitude is more than doubled the effect in high-stale funds. These novel results suggest that some staleness in NAV may be desirable during stressed times.

Fourth, when liquidity is high, the outflow–ΔFFTar relationship is stronger in a low-interest-rate environment. As bond values are decreasing and convex in interest rate, a given increase in interest rate causes a larger change in bond values and, due to staleness, a larger mispricing. As liquidity worsens, investors' redemption is less driven by mispricing and more by redemption externality. Hence the outflow–ΔFFTar relationship varies less across loose and tight monetary policy environment. Consistently, we observe a strong outflow–ΔFFTar relationship in months with accommodative monetary policy and liquid market conditions. However, in stressed periods or for illiquid funds, capital flows out from funds more aggressively in response to FFTar increases when monetary policy is tight. Therefore, policymakers should particularly put eyes on illiquid funds during market downturns in a contractionary monetary policy regime.

We provide further results that are consistent with the mechanism. We perform the same set of test on Treasuries funds and find no outflow–ΔFFTar relationship. This result is consistent with our mechanism because treasuries are traded much more frequently in a very liquid market. In fact, we show NAVs of Treasuries funds are not stale and hence little mispricing is likely to be present. In addition, we show that institution-oriented funds have weaker outflow–ΔFFTar relationship than retail-oriented funds. A possible explanation is that the former is more likely to have concentrated, large owners who then internalize more the redemption externality.[5]

Literature review This paper closely relates to works on the financial fragility of open-end mutual funds, which stems from the investors' payoff complementarities in redemptions. On the theory side, Chen, Goldstein, and Jiang (2010) examine how asset illiquidity increases the payoff complementarities and thus fragility in equity mutual funds. Liu and Mello (2011) and Zeng (2017) study the optimal liquidity management of funds to reduce fragility. Morris, Shim, and Shin (2017) and Goldstein (2017) ask when fund managers should hoard cash in anticipation of redemptions in the future. Empirical works have devoted to documenting the existence of fragility in different mutual funds. Adrian, Estrella, and Shin (2019) 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) find that fund outflows are positively correlated with declines in NAV, creating incentives for bond investors to leave funds 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 equity and bond fund investors. Using structural recursive vector autoregression (VAR), Banegas, Montes-Rojas, and Siga (2016) also document that bond fund flows instrumented by the unexpected monetary policy are closely related to fund performance, indicating a first-mover advantage among investors. At a 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. All the above models and empirical evidence focus on fragility induced by illiquidity. Our paper highlights a novel notion of fragility induced

[5] A similar result is found in Goldstein, Jiang, and Ng (2017).

by monetary policy.

The only papers modeling monetary policy and asset management sector together are Morris and Shin (2015) and Feroli et al. (2014). The model predicts a jump in risk premium when the central bank signals a higher interest rate. They assume that asset managers bear a cost of ranking last in the relative performance. When the central bank adjusts the return of the safe asset up, the cost of coming last alters managers' preference towards the safe option. Hence, managers sell the risk asset, pushing up its risk premium. The model is novel and can be generalized to different mutual funds. However, Banegas, Montes-Rojas, and Siga (2016) document the opposite effects of monetary policy on flows to equity mutual funds versus bond mutual funds. In contrast, our model is specific to bond mutual funds. We point out that the convexity in bond price is the key to bridge 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. Adriana and Liang (2018) provide 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) show that an accommodative monetary policy increases intermediaries' incentives to take leverage. Di Maggio and Kacperczyk (2017), 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 environments could contribute to financial fragility in corporate bond funds because it strengthens the fund investors' incentives to redeem. This is a new source of unintended consequences of monetary policy.

2 Hypotheses development

Our main mechanism is about the fund investors' decision to redeem or to stay in corporate bond funds in the face of uncertain interest rate changes. Two key features of corporate bonds make outflows in funds responsive to interest rate changes. First, the infrequent trading of corporate bonds makes bond funds' NAV stale, creating potential mispricing in NAV to be exploited by investors. Second, the illiquidity of corporate bonds implies that the liquidation of bonds triggered by redemption will be costly. Since the NAV does not reflect this future liquidation cost, investors who stay in the fund will bear the cost, inducing them to redeem in the first place. We construct a model to capture these strategic considerations by fund investors and derive several empirical predictions, as discussed below. The model details can be found in Appendix .

Hypothesis 1. *There is a positive relationship between fund outflows and change in Federal Funds Target rate.*

The first hypothesis is our notion of monetary-policy-indcued fragility in corporate bond funds. It arises due to the temporary mispricing of the NAV. An increase in the Federal Funds Target rate tends to decrease bond and thus corporate bond fund values, stale NAV implies that the NAV is temporarily overpriced. Hence, investors have stronger incentives to redeem their shares.

Hypothesis 2. *Funds with less liquid assets exhibit stronger sensitivity of outflow to change in Federal Funds Target rate. The same prediction holds for funds in illiquid periods.*

The second hypothesis stems from the concern of redemption externality. As an increase in the Federal Funds Target rate causes temporary overpricing in NAV, investors have the incentive to redeem their shares. Their redemption, in turn, leads to costly liquidation of the corporate bonds. As liquidity worsens, investors who stay would bear higher costs, inducing them to redeem their shares.

Hypothesis 3. *When liquidity is high, staler funds exhibit stronger sensitivity of outflow to change in Federal Funds Target rate. As liquidity decreases, staleness increases less and eventually reduces the sensitivity.*

The third hypothesis highlights the interactive effects of illiquidity and staleness. In the case of high liquidity, fund investors are not concerned with redemption externality. They behave like arbitrageurs who redeem when the shares are overpriced. Following an increase in the Federal Funds Target rate, staler NAVs, by definition, reflect a smaller fraction of the total decrease in bond values. Hence the overpricing in the NAV is more severe, inducing more fund investors to redeem. In contrast, when liquidity is low, fund investors are primarily concerned with the redemption externality, and thus profiting from mispricing becomes less relevant. Extreme illiuquidity could prompt investors to redeem even if the bond values are expected to rise. In these cases, staler NAVs rise less, *reducing* investors' incentive to redeem.

Hypothesis 4. *When liquidity is high, funds exhibit stronger sensitivity of outflow to change in Federal Funds Target rate in a loose monetary policy environment. As liquidity decreases, looseness in monetary policy increases less and eventually reduces the sensitivity.*

As discussed in the previous hypothesis, the mispricing of NAV is the main driver of outflow when liquidity is high. For a given increase in target Fed Fund rate, the bond values decrease more, hence NAV is more overpriced, in a low-interest-rate environment because bond values are decreasing and convex in interest rates. Hence, investors redeem more in such environment. In cases with extremely illiquidity, investors would stay only if the bond values are expected to rise by a large amount. Then, a loose monetary policy environment helps reduce outflow because a given decrease in interest rate leads to a larger increase in bond values.

3 Data and Sample

3.1 Data

Corporate bond mutual funds. The data on corporate bond mutual funds is extracted from 1) the the Center for Research in Security Prices (CRSP) Survivor-Bias-Free U.S. Mutual Fund database and 2) the Morningstar Direct.

Characteristics: We start with the data from the CRSP mutual fund database to construct a sample of corporate bond mutual funds, following Goldstein, Jiang, and Ng (2017). The sample runs from January 1992 to December 2019.[6] We select corporate bond mutual funds based on their objective codes provided by CRSP.[7] Index corporate bond mutual funds, exchange-traded funds, and exchange-traded notes are excluded. We restrict the sample to fund shares with more than one-year history in the sample period. We further remove fund share-month entries without return or total net asset (TNA) information, and discard fund share-month entries with more than 100% increase or decrease in TNA over a month. Our final sample contains 5,765 unique fund share classes in 2,019 unique funds.[8] The data also contains detailed fund characteristics, such as fund expense ratio, maturity, percentage of cash and government bond holding, and high-yield fund indicator.

Flows and total net asset (TNA). We obtain monthly returns, monthly TNA, as well as daily returns from the CRSP mutual fund database. The net fund flow of fund share i at month t is

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[6] There are few corporate bond mutual funds in the database prior to 1991. The performance of each bond fund share is estimated using one year of data, so the data of 1991 is excluded.

[7] 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'.

[8] One bond fund can issue several shares, tailored to different customers. Although these fund shares have the same holdings and valuation, their varied characteristics, such as fees and investment horizons, can affect investors' purchase and redemption decisions, and hence, fund flows. So we use fund share as the unit of analysis.

calculated as

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

where $R_{i,m}$ is the return of fund share i over month m, and $TNA_{i,m}$ is the end-of-month total net asset value.

The data on daily flows at the fund share level is extracted from MorningStar Direct (MS). MS has started to collect self-reported TNAs since July 2007. As daily TNAs are reported by funds at their discretion, we see inconsistency in funds' reporting. For example, some funds only report at the month-end, while some report every trading day. Therefore, we apply a filter to construct our sample. We merge MS and CRSP databases using ticker information following Berk and Van Binsbergen (2015). We keep bond fund shares if they 1) appear in the corporate bond fund sample constructed using the CRSP database and 2) have consecutive daily flows to construct cumulative flows in window [-10, 5] around FOMC meetings. After the filtering, there are sparse funds shares before 2009.[9] We restrict our sample from January 2009 to December 2019. The final daily sample contains 2,750 unique fund shares.

FFTar. The U.S. Federal Reserve sets target federal funds rate (FFTar), which is the rate at which depository institutions (banks) lend reserve balances to other banks on an overnight basis. We adopt FFTar, extracted from Federal Reserve Economic Data (FRED).[10] We also extract the dates of FOMC meetings from Federal Reserve. Our sample covers a total of 240 months with FOMC meetings.

[9] There are less than 80 funds shares left before July 2008. The fund shares increased to 1,500 in July 2008 and kept increasing afterward.

[10] Before 2008, the FFTar series, DFEDTAR of FRED, is used. After 2008, a target rate corridor is introduced, we average the upper limit, DFEDTARU, and lower limit, DFEDTARU, as the FFTar.

Other variables. We measure the market-level corporate bond illiquidity using the VIX index from the Chicago Board Options Exchange (CBOE)[11]. We approximate the fund share level illiquidity using the proposition of cash and government bonds holdings recorded in CRSP. We also construct fund performances (Perf), following Goldstein, Jiang, and Ng (2017).[12]

We also consider other potential macro drivers for fund flows to the corporate bond mutual funds, including the yield slope and the default spread. The yield slope is calculated as the yield difference between the 30-year and one-year Treasury yields. The default spread is the yield difference between BBB- and AAA-rated corporate bonds, extracted from FRED.

3.2 Summary Statistics

Table 1 presents the summary statistics for daily data in Panel A and monthly data in Panel B. We winsorize all fund-share variables at the 1% quantile from each tail. On average, during both sample periods, capital flows into corporate bond mutual funds. The average daily inflow is 0.04% of TNA from 2009 to 2019, and the average monthly inflow is 0.9% from 1992 to 2019. The two magnitudes are largely consistent. In those 10-day windows before FOMC meetings after 2009, we find an average of 0.32% inflows to corporate bond funds.

Other reported statistics at the monthly level are consistent with Table 1 in Goldstein, Jiang, and Ng (2017). The corporate bond mutual funds deliver an average positive daily return of 0.02%

[11] Dick-Nielsen, Feldhütter, and Lando (2012) build a bond market illiquidity index, which starts in July 2002. This index has a 87.5% Pearson correlation with the VIX index. To avoid the loss of sample, we adopt the VIX index to measure the bond market illiquidity.

[12] The performance of fund i at month t is measured as the past one year's alpha from the following time-series regression:

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

where $R^e_{i,\tau}$, $R^e_{B,\tau}$ and $R^e_{M,\tau}$ denote excess returns of the fund share i, the aggregate bond market and the aggregate stock market, respectively. The risk-free rate is approximated by 1-month London Interbank Offered Rate (LIBOR). $R^e_{B,\tau}$ is approximated by the Vanguard total bond market index fund return from Bloomberg and $R^e_{M,\tau}$ is approximated by CRSP value-weighted market return.

and monthly return of 0.39%. The average size of funds is \$373.47 million, and the average age is 9.33 years. On average, the funds hold 2.39% cash and 11.78% government bonds in the portfolio. Both mean and median of performance are negative.

4 Empirical Results

This section devotes to empirically testing the hypotheses stated in Section 2.

4.1 Outflow-ΔFFTar Relationship

Our main hypothesis is that anticipating an increase (decease) in FFTar, investors withdraw (deposit) capital from (to) corporate bond funds ahead of meetings due to the stale pricing and the temporarily mispring of NAVs. This channel generates a positive relationship between fund outflows before meetings and change in Federal Funds Target rate.

4.1.1 Evidence using daily data

Evidence for NAV mispricing. To clearly pinpoint this channel, we analyze daily flows and returns of bond funds over a narrow window around FOMC meetings. There are two key premises to generate the temporary mispricing in NAVs before meetings. First, investors could anticipate correctly the policy rate changes, and hence fundamental values of bonds and bond funds should adjust along with their expectation. Second, the bond fund NAVs are stale and do not reflect the changes in investors' expectation. We provide evidence for these two premises.

Inspired by Cochrane and Piazzesi (2002), we examine whether market-traded derivatives on Federal Funds rates reveal information correctly regarding the coming FOMC meetings, using the following specification:

$$\Delta FFTar_{[-1,1]} = \Delta FFuture_{[-10,-1]} + \epsilon_t, \tag{2}$$

where $\Delta FFTar_{[-1,1]}$ is the FFTar change announced at each FOMC meeting, and $\Delta FFuture_{[-10,-1]}$ is the changes of 30-day Federal Funds Future in a 10-day window before the corresponding meeting. This simple time-series regression studies whether ahead-of-meeting future rate changes predict the Fed's decision on FFTar.

Table 2 presents the results. Significantly positive coefficients suggest a very strong predictive power of Federal Funds Futures both in the full sample and in the sub-sample after the financial crisis. One-month Eurodollar rate also displays a strong predictive power over the full sample, but the power is weaker after 2009. Figure 3 plots the paired dots of future rate changes and FFTar changes. The triangle dots represent meetings where the sign of future rate moves is in line with that of FFTar changes. During the sample from 2009 to 2019, there were in total 12 meetings that announced changes in FFTar, and 9 of them were correctly predicted by the ahead-of-meeting future rate changes. In the full sample period, 54 out of 75 FFTar changes are correctly forecasted before meetings. The above evidence points investors' ability to predict changes in FFTar, which be a result of the Fed's communications before meetings.

We next provide evidence that NAVs of corporate bond funds do not react to investors' new information. The NAVs are stale because their daily calculations are based on transaction prices of bonds in the portfolio and bonds are infrequently traded.[13] We proxy the staleness of NAVs by the proportion of non-moving NAVs days in the window [-20,-10] before FOMC meetings for each bond fund. Larger proportion suggests staler NAVs. Panel (a) in Figure 4 plots the distribution of this staleness measure. We classify bond funds with a higher-(lower-)than-median staleness as high-(low-)stale funds. In Table A.1, we show high-stale funds, on average, hold less cash and

[13] A natural question to ask is why bond investors do not trade to profit from the stale prices in bonds. It is likely that such arbitrage is infeasible because when investors approach dealers to trade, rational dealers would update their quotes according to the new information.

government bonds, are less likely to be high-yield funds, and have a shorter maturity, but they do not differ much in fund size, age, and the likelihood to be mainly invested by institutional investors.

We examine how fund NAVs move around FOMC meetings, separately for high v.s. low stale funds. We run the event study as follows:

$$\Delta NAV_{i,[\tau_1,\tau_2]} = \Delta \text{FFuture}_{[-10,-1]} \text{ or } \Delta \text{FFTar}_{[-1,1]} + \text{Controls}^F_{i,t-1} + \alpha_i + \varepsilon_{i,d}, \tag{3}$$

where $\Delta NAV_{i,[\tau_1,\tau_2]}$ is the cumulative log NAV changes for fund share i in windows $[\tau_1, \tau_2]$ around FOMC meetings, and α_i is fund share fixed effects. $\text{Controls}^F_{i,t-1}$ are one-year lagged fund characteristics, including the total net asset in log scale, expense ratios, percentage of cash and government bond holding, high-yield fund indicator, and maturity. Adding controls alleviates concerns that our results are driven by other fund characteristics rather than staleness in NAVs. We weight each observation by the previous year's fund TNA value, to assess the overall impact on the aggregate bond fund sector. Standard errors are clustered at each FOMC meeting and the fund share level.

The results are reported in Table 3. We consider moves in NAVs in three windows around FOMC meetings: [-10,-1], [-1,2], and [-1,5]. In panel A, we show that for high-stale funds, their NAVs do not move with information revealed by Fed Futures before meetings and start to adjust in the opposite direction with FFTar changes after meetings. For a 25-basis-point increase in FFTar, NAVs of stale funds drop by 8.8 (≈0.353/4) basis points (column 4) in two days following meetings and by another 5.5 (≈(0.572-0.353)/4) basis points (column 6) in three days afterward. The coefficient magnitudes are similar under different specifications with or without control variables. Panel B reports patterns of NAV moves for low-stale funds. NAVs are negatively correlated with future rate moves before meetings, shown in the first two columns. After meetings, NAVs still marginally adjust to new information in a short two-day window, but not anymore afterward.

We draw two conclusions from these two tables. First, NAVs of high-stale funds do not reflect market information ahead of FOMC meetings, while NAVs of low-stale funds do. Second, NAVs of high-stale funds adjust strongly after FOMC meetings, although the adjustment takes some time. In contrast, NAVs of low-stale funds do not adjust that much after meetings as they strongly react to market information ahead of meetings. Putting together, these results imply that there is a temporary mispricing in the NAVs of high-stale funds before FOMC meetings.

Consequences of NAVs mispricing. As bond investors can redeem shares at end-of-day NAVs, opportunistic investors could profit from the temporary mispricing before the meetings. We show this using the same specification as (3) but replace the independent variable by cumulative flows in windows [-10,-1] and [-5,-1] before FOMC meetings.

We report results in Table 4. Columns (1)-(2) in Panel A report significantly positive coefficients on $\Delta \text{FFTar}_{[-1,1]}$, suggesting that investors withdraw capital from the funds if anticipating a positive rate change to be announced in FOMC meetings. Quantitatively, a 25-basis-point increase in FFTar is associated with a 0.17% (≈0.68/4)increase in fund outflows in a 10-day window before FOMC meetings (column 2). In fact, the outflows concentrate in a short 5-day window before meetings. In columns (3)-(4), we shrink the window to 5 days before meetings to calculate outflows. The coefficient of (4) is only slightly smaller than that of column (2), suggesting that the outflow–ΔFFTar is weak in the window [-10, -6] before meetings.[14] Such precise timing ensures that our results are not driven by factors other than monetary policy.

In contrast, the results in panel B show that bond investors' front-running behaviors are not statistically significant in low-stale funds. As these funds' NAVs update with ahead-of-meeting Fed Future rates, there is less scope for profiting from the mispricing in NAVs.

In Figure 5, we plot dollar gains from opportunistic redemption for every FOMC meeting from 2009 to 2019. We calculate gains that investors withdraw (deposit) capital in a 10-day window before FOMC meetings when they anticipate bond fund NAVs drop (increase) in the [-1,2] window

[14] We confirm this result in unreported tables.

around FOMC meetings:

$$Gain = -\sum_i OutFlow_{i,[-10,-1]} * \Delta log(NAV_{i,[-1,2]}).$$

The average dollar gain for early withdrawal investors is 20.98 million dollars per meeting. The number boosts to 96.13 million dollars for 12 meetings with FFTar updates, highlighted in red. The dollar gains are non-trivial. By dividing the dollar gains by the amount of flow volume in dollars, we estimate that opportunistic investors profit 84 basis points on average in a 10-day window before FOMC meetings. Importantly, the gain from opportunistic investors is the cost borne by long-term investors who stay in the funds.

Complementary results from Treasuries and Equities funds. It is plausible that changes in FFTar can affect fixed-income funds across the board and cause investors to rebalance their portfolio from corporate bond to other asset classes. Here, by studying treasuries and equities funds, we find little support for these alternative mechanisms and provide further evidence consistent to our stale-pricing mechanism.

First, panels (b) and (c) of Figure 4 show that both treasuries and equities funds are much less stale than corporate bond funds. Second, panel A of Table A.2 confirms that that even NAVs of relatively stale treasuries funds react strongly to changes in Federal Funds Futures before meetings, suggesting little mispricing in NAVs. For equities funds, panel B shows that there is no significant relationship between NAVs and changes in Fed Funds Futures. Third, no significant outflow–ΔFFTar relationship is found in either treasuries or equities funds (see Panel A and B of Table A.3). Overall, the absence of results in treasuries and equities funds suggests that it is staleness in NAVs, rather than, respectively, characteristics of fixed-income products or portfolio reallocation, that drives our monetary-policy-induced fragility in corporate bond funds.

4.1.2 Evidence using monthly data

The daily analysis provides sharp causal evidence on how monetary policy affects corporate bond fund flows. However, the short sample period raises a question regarding how general the results are. In this section, we extend our analysis back to 1992 using monthly data to gain some knowledge regarding the general patterns.

We perform the following panel regression:

$$OutFlow_{i,m} = \Delta\text{FFTar}_m + \text{Controls} + \alpha_i + \varepsilon_{i,m} \quad (4)$$

where $OutFlow_{i,m}$ measures the outflows from fund share i over month m and the key independent variable ΔFFTar_m is the change in FFTar over the same month m. To rule out the concern of omitted variables, we include potential macro-and micro-drivers for fund flows as control variables. Macro controls include 1) the term-structure of corresponds bonds, approximated by the change in yield indifference between 30-year and 1-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.[15] Micro controls are fund share characteristics at month m, including fund performance from regression (1), last month's fund return, natural log of the total net asset, high-yield fund indicator, and expense ratio. We restrict the analysis in months with FOMC meetings only to reduce noises, and weight each observation by last month's fund TNA value. To allow for an intertemporal dependence of flows across funds and across time, we cluster standard errors at the fund share and month levels.

We measure the staleness of a fund using the proposition of non-moving NAV days in the *previous* month, and then classify bond funds with a higher-(lower-)than-top-(bottom-)tercile staleness as high-(low-)stale funds. Panel B of Table 4 report results on outflow–ΔFFTar relationship for high v.s. low stale funds. Consistent with daily evidence,we find that outflow-ΔFFTar relationship

[15] Choi and Kronlund (2017) consider these three variables as potential macro drivers for reaching for yield in the corporate bond mutual funds.

is stronger in high-stale funds.

4.2 Monetary-policy-induced Fragility

The mispricing-induced outflow–ΔFFTar relationship appears no matter which direction FFTar moves. In anticipation of a drop (increase) in FFTar, investors deposit (redeem) capital to purchase under-valued (over-valued) fund shares before FOMC meetings. However, unlike capital withdrawals, capital inflows do not engender strategic complementarities among investors.[16] Therefore, we expect a stronger outflow–ΔFFTar relationship when the FFTar is expected to increase. Table 5 presents asymmetric outflow–ΔFFTar relationship in months with non-positive and non-negative FFTar moves. During months with non-negative FFTar changes, we see 0.44% ($\approx 1.771/4$) outflows for a 25-basis-point increase in the FFTar (column 4), more than 100% higher than in months with non-positive FFTar changes (column 6). This pattern supports the notion of redemption externality. Therefore, corporate bond funds are fragile during times with potential increases in FFTar, which we denote as monetary-policy-induced fragility.

In the next sections, we focus on understanding what factors intensify the monetary-policy-induced fragility.

4.2.1 The Effect of Illiquidity on Monetary-policy-induced Fragility

Hypothesis 2 states that illiquidity intensifies the redemption externality and thus should strengthen the outflow–ΔFFTar relationship. To test this, we split our sample based on a fund's liquid asset holding in the year before FOMC meetings. We classify funds with higher-(lower-)than-sample median cash and government bond holdings as liquid (illiquid) funds. Then we perform the same analysis as in Table 4 for sub-samples of liquid and illiquid funds.

[16] To see this asymmetry, consider a fund that has shares underpriced relative to the fundamental values of its portfolio assets. By creating new underpriced shares, the fund incurs a loss and hence the underpricing is reduced.

The results are reported in Panel A of Table 6. Consistent with redemption externality, the coefficient loadings of $\Delta FFTar_{[-1,1]}$ are significantly positive only for the sub-sample of illiquid funds. Quantitatively, investors withdraw 0.28% (≈1.109/4) capital from *illiquid funds* in a 10-day window before meetings with a potential 25-basis-point increase in FFTar. In the unreported table, we repeat the analysis by adding the staleness measure in controls and get an effect size of 0.26%, which is very close to 0.28%. This suggests that within fund shares with similar staleness, illiquid funds exhibit a stronger outflow–ΔFFTar relationship.

Using monthly data, we extend the analysis to study the impact of illiquid market conditions, thanks to a long sample period. We measure the bond market illiquidity using the VIX index, and split months to liquid (illiquid) periods when the VIX index is below (above) the bottom (top) tercile over the sample period. Then we repeat the analysis as in column (4) of Table 5. We focus on months with non-negative FFTar changes because only outflows generate redemption externality.

First two columns of Panel B of Table 6 presents the results. Again, we only observe a strong outflow–ΔFFTar relationship in months with a high VIX index (column 1). A 25-basis-point increase in the FFTar, on average, is accompanied by 0.77% (≈3.090/4) outflows. Importantly, this effect size is around 75% larger than the average effect of 0.44% shown in column (4) of Table 5. In the last two columns, we perform a similar analysis for sub-samples classified by fund-share illiquidity (measured by the liquid asset holding), and find the same conclusion.

Overall, results in this section show that illiquidity exacerbates monetary-policy-induced fragility in corporate bond funds.

4.2.2 The Impact of of Staleness on Monetary-policy-induced Fragility in Illiquid Funds or Periods

The above result shows that monetary-policy-induced fragility is much more severe in illiquid funds or periods. In this section, we highlight a seemingly counter-intuitive result that staleness in NAVs can be *stabilizing* in these cases.

The effect of staleness is discussed in Hypothesis 3. Staleness in NAVs contributes to mispricing in bond funds. When liquidity is high, investors can profit from this mispricing by redeeming overpriced shares when bond values are predicted to drop below the NAV. When liquidity is low, fund investors are primarily concerned with the redemption externality and might redeem even if the bond values are anticipated to be higher than the current NAV. In this case, because it moves closer to the higher bond values, a less stale NAV is a higher NAV which increases investors' incentive to redeem. Therefore, *low staleness* in NAVs exacerbates monetary-policy-induced fragility in illiquid funds or periods.

This prediction is confirmed in Table 7. In Panel A (B), we report results using daily (monthly) data. Within illiquid funds in Panel A, we see larger outflows for *low-stale* funds before meetings: a 25-basis-point increase in FFTar is associated with a 0.45% increase in fund outflows in a 10-day window before FOMC meetings. This magnitude is more than doubled the effect in high-stale funds. In Panel B, we also find a stronger outflow–ΔFFTar effect in low-stale funds when market is illiquid or funds illiquid.[17] These results point to a novel finding that staleness in NAV may be desirable during stressed times.

4.2.3 The Impact of Policy Environments on Monetary-policy-induced Fragility

According to Hypothesis 4, the outflow–ΔFFTar relationship is stronger in a low-interest-rate environment, when liquidity is high. This prediction is built on the convex relationship between interest rate and bond values. In a loose monetary environment, a given increase in interest rate causes a larger change in bond values and, due to staleness, hence a larger mispricing. Again, as argued above, such mispricing leads to arbitrage opportunities for investors in liquid times.

[17] As a check, we report the results in liquid funds or periods in Table A.4 of the Appendix. Within liquid funds in Panel A, we confirm that high-stale funds exhibit stronger outflows than low-stale funds prior to FOMC meetings with potentially positive FFTar updates.

To test this prediction, we use the longer monthly data to split sample into regimes with different monetary policy environment. Specifically, we classify months into an accommodative (contractionary) policy regime when FFTar is below (above) the bottom (top) tercile over the sample period. Then we add interaction terms of policy regime to the specification (4) as

$$\begin{aligned} OutFlow_{i,m} &= \Delta\text{FFTar}_m * \mathbb{1}(\text{Low}^T\ \text{FFTar}_m) + \text{Controls} * \mathbb{1}(\text{Low}^T\ \text{FFTar}_m) \\ &+ \alpha_i * \mathbb{1}(\text{Low}^T\ \text{FFTar}_m) + \varepsilon_{i,m} \quad \forall \text{liquid funds/periods}, \end{aligned} \tag{5}$$

To ensure a relatively high liquidity, we consider a sub-sample liquid periods or liquid funds as defined in Section 4.2.1. We include interaction terms for all control variables and fixed effects such that the estimation of interaction term $\Delta\text{FFTar}_m * \mathbb{1}(\text{Low}^T\ \text{FFTar}_m)$ is unbiased.

Table 8 presents test results for liquid periods (Panel A) and liquid funds (Panel B). The coefficient loadings on $\Delta\text{FFTar}_m * \mathbb{1}(\text{Low}^T\ \text{FFTar}_m)$ are significantly positive in column (1) of both panels, suggesting that the sensitivity of investors' redemption in response to a rise in interest rate increases in a lower Fed fund rate regime.

However, in column (2) of both panels, we see opposite results: During illiquid periods or in illiquid funds, capital flows out from funds more aggressively in response to FFTar increases when monetary policy environment is tight. This is also consistent with the model prediction. As liquidity worsens, investors' redemption is less driven by mispricing and more by redemption externality. In cases with extremely illiquidity, investors would stay only if the bond values are expected to rise by a large amount. Then, a tight monetary policy environment exacerbates outflow because a larger interest rate drop is required to cause a given amount of increase in bond values.

Overall, the outflow–ΔFFTar relationship is the strongest during illiquid months in a contractionary monetary policy regime: for a 25-basis-point increase in the FFTar, on average, monthly outflows increase by 0.56%. These results raise concerns for unexpected consequences of monetary policy on the bond mutual fund industry.

5 Conclusion

Since the global financial crisis of 2008, the Federal Reserve has been actively maintaining a low Federal Funds Target rate to ease the financing conditions of the real sector. Nevertheless, academics and regulators have voiced concerns regarding various potential negative consequences of the expansionary monetary policy. In this paper, we propose a novel channel via which monetary policy can contribute to the fragility in an increasingly important area of the intermediation system, namely, the corporate bond mutual fund sector. Policymakers might thus want to be mindful of this negative consequence of monetary policy.

We end with highlighting the novel policy implications following from the results of our analyses. First, staleness in NAVs could dampen outflow during stressed periods. Second, changes in policy rate has particularly strong effects on outflow during illiquid periods in a tight policy regime. These results suggest that policies or regulations that aim to enhance the stability of corporate bond funds should be contingent on funds' staleness and monetary policy environment.

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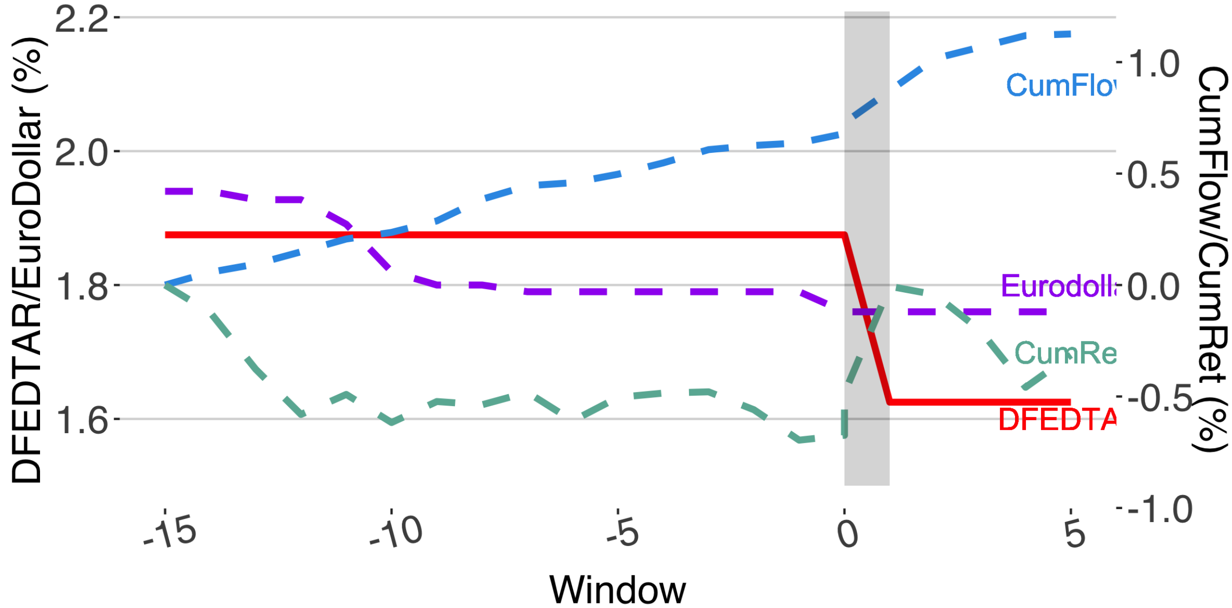
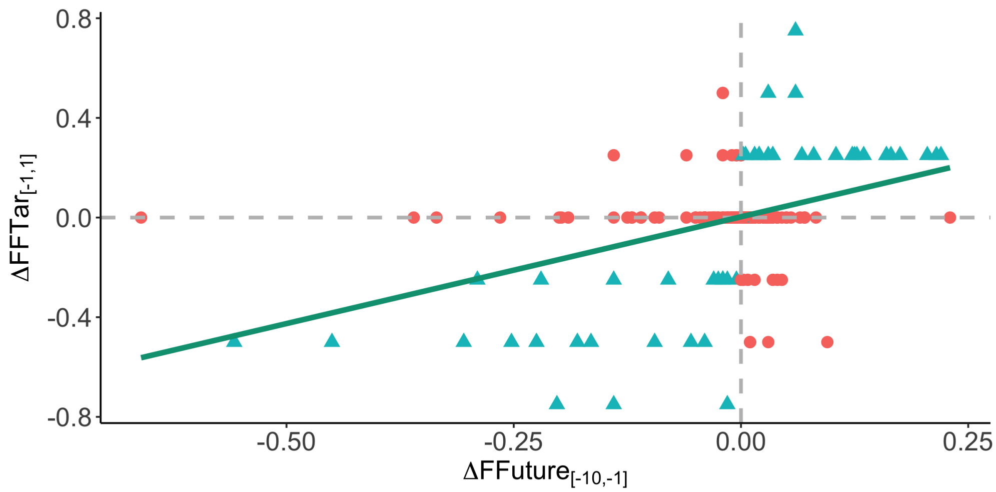


Figure 2: The time-series plot of the Federal Funds Target rate (in red), one-month Eurodollar deposit rate (in purple), the cumulative return (in green) and the cumulative flow (in blue) of aggregate corporate bond funds around FOMC meeting on October 29, 2019.

(a) 1992-2019



(b) 2009-2019

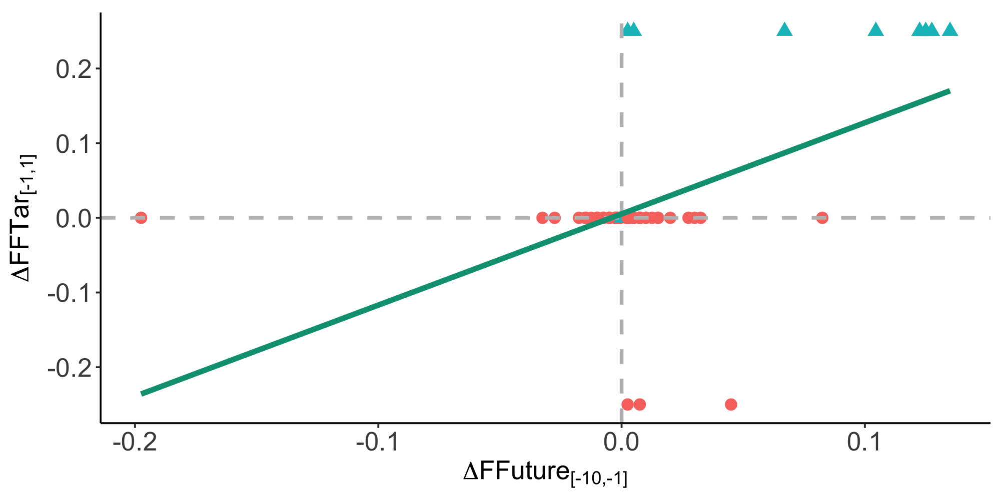


Figure 3: Future Federal Funds Target Rate Changes are Predictable Figures present the relationship between the 30-day Federal Funds Future rate changes in window [-10,-1] before each FOMC meeting and the corresponding change in Federal Funds Target rate announced in the meeting. The triangle blue points indicate the meetings that pre-meeting future rate changes correctly predict the sign of Federal Funds Target rate changes.

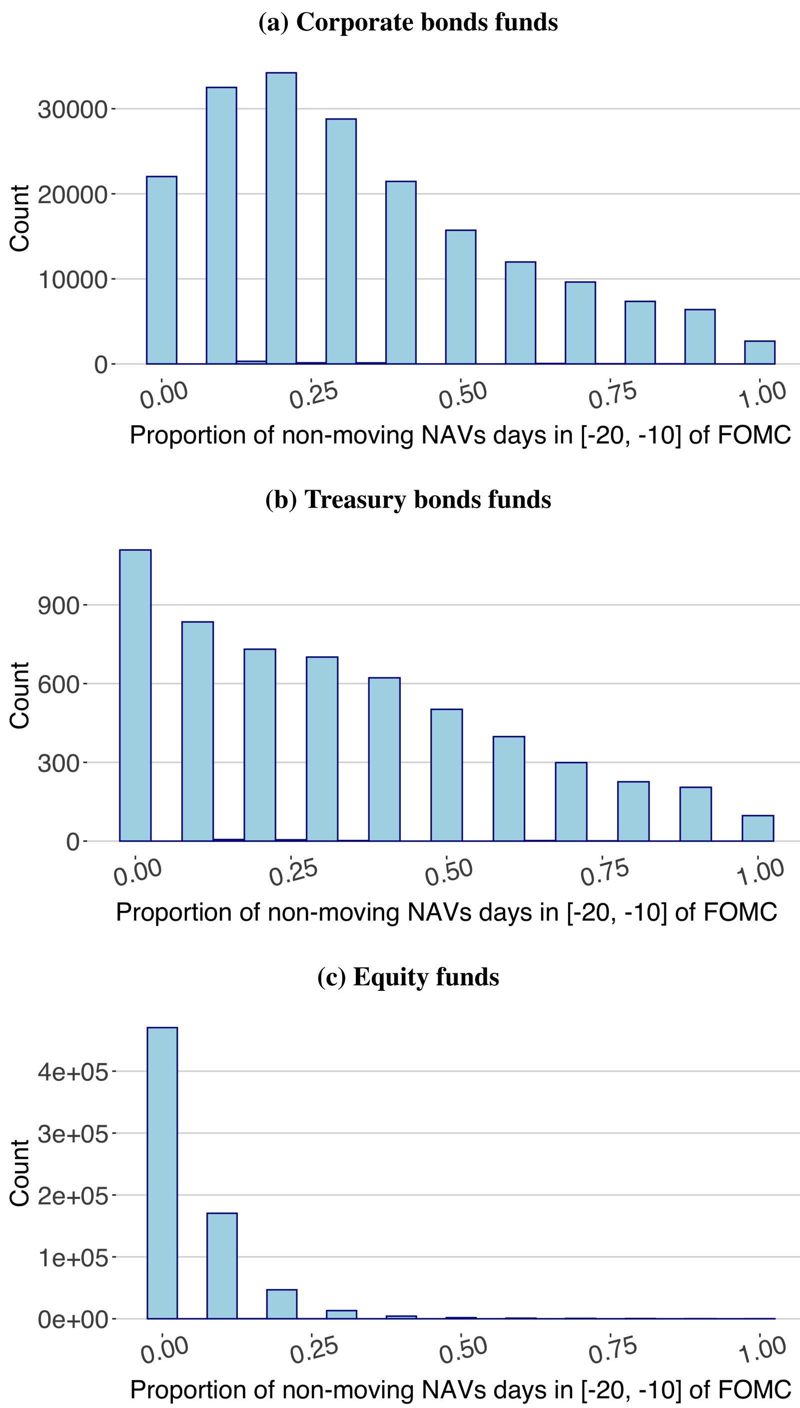


Figure 4: Staleness of Various Funds. Figures plot the proportion of non-moving NAVs days in the window [-20,-10] before FOMC meetings for corporate bonds funds (panel a), treasury bond funds (penal b) and equity funds (panel c). The sample include all FOMC meetings from January 2009 to December 2019.

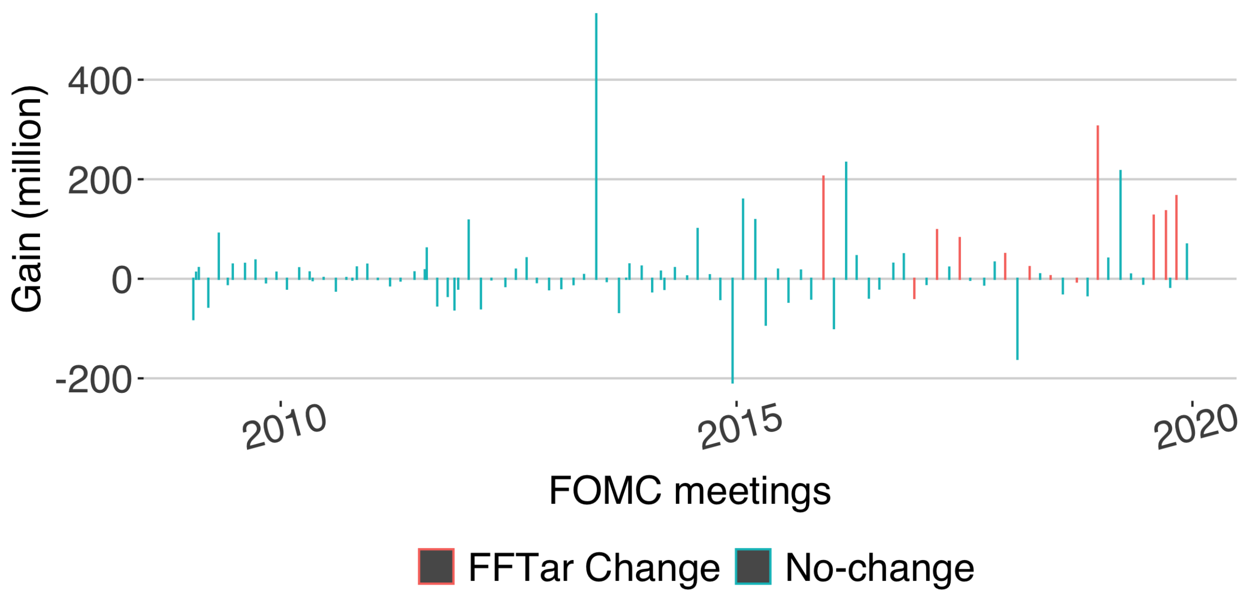


Figure 5: Dollar Gain from Opportunistic Redemption The figure plots the dollar gain calculated based on the following equation for each FOMC meetings:

$$Gain = -\sum_i OutFlow_{i,[-10,-1]} * \Delta log(NAV_{i,[-1,2]}).$$

It represents gains that investors withdraw (deposit) capital in 10-day window before FOMC meetings when they forecast bond fund NAVs will drop (increase) in [-1,2] window around FOMC meetings.

Panel A: Daily Data (2009 to 2019)

	N	Mean	Std Dev	P5	P25	Median	P75	P95
Daily outflow (%)	5,225,399	-0.042	0.429	-0.553	-0.094	-0.006	0.060	0.342
Daily return (%)	5,570,871	0.020	0.204	-0.309	-0.090	0.000	0.104	0.363
$\text{OutFlow}_{[-10,-1]}$ (%)	143,884	-0.323	2.438	-3.917	-0.782	-0.068	0.464	2.394
$\text{OutFlow}_{[-5,-1]}$ (%)	143,820	-0.151	1.479	-2.250	-0.409	-0.019	0.269	1.450

Panel B: Monthly Data (1992 to 2019)

	N	Mean	Std Dev	P5	P25	Median	P75	P95
Outflow (%)	601,753	-0.914	8.189	-13.512	-1.813	0.155	1.612	7.372
Return (%)	601,753	0.391	1.297	-1.781	-0.158	0.360	1.027	2.442
TNA (million)	601,753	373.483	1010.321	0.200	8.200	51.400	238.700	1783.440
Age (years)	601,753	9.334	8.304	0.912	3.337	7.099	13.167	24.362
Expense (%)	533,087	1.009	0.485	0.360	0.650	0.900	1.350	1.900
Cash Holding (%)	517,275	2.395	10.513	-14.210	0.000	2.000	5.020	17.790
Government Bond Holding (%)	517,275	11.785	16.931	0.000	0.000	1.910	19.830	48.860
Maturity (years)	357,689	8.086	15.055	2.400	6.200	8.700	13.000	18.300
Perf (%)	543,627	-0.122	0.426	-0.762	-0.336	-0.112	0.033	0.608
η_B	543,627	0.653	0.466	-0.079	0.309	0.716	0.963	1.322
η_M	543,627	0.130	0.164	-0.022	0.012	0.061	0.210	0.483

Table 1: Summary Statistics of Fund Characteristics. This table presents the summary statistics for characteristics of corporate bond mutual funds based on CSRP and Morningstar data. The daily data runs from January 2009 to December 2019 for 2,750 funds, and the monthly data runs from January 1991 to December 2019 for 5,765 unique fund share classes in 2,019 unique funds. (Daily) Outflow is the fund outflow in a given (day) month in percentage point. (Daily) Fund return is the (daily) monthly net fund return in percentage point. $\text{OutFlow}_{[-10,-1]}$ ($\text{OutFlow}_{[-5,-1]}$) is the cumulative log NAV changes for fund share i in windows [-10,-1] ([-5,-1] around FOMC meetings. TNA is the total net assets, Age is the fund age in years since its inception in the CRSP database. Expense is fund expense ratio in percentage point. Cash Holdings is the proportion of fund assets held in cash in percentage point. Government Bond Holding is the proportion of fund assets held in government bonds in percentage point. Maturity is the weighted average maturity in years. Perf, η_B, η_M are coefficients from regression (1) for each fund share. We exclude exchange-traded funds and exchange-traded notes from the CRSP mutual fund database. To mitigate the influence of outliers, we winsorize all continuous variables at the 1% quantile from each tail.

	$\Delta FFTar_{[-1,1]}$			
	Year≥ 1992		Year≥ 2009	
	(1)	(2)	(3)	(4)
ΔFFuture$_{[-10,-1]}$	0.857***		1.222***	
	(7.729)		(6.369)	
ΔEuroDollar1m$_{[-10,-1]}$		0.285***		0.406*
		(7.088)		(1.919)
Constant	0.003	−0.007	0.005	0.013
	(0.284)	(−0.649)	(0.697)	(1.469)
Observations	272	272	98	98
Adjusted R^2	0.178	0.154	0.290	0.027

Table 2: Predictive Regressions for Federal Fund Target Rate Changes around FOMC Meetings: This table presents the results of predictive regressions for changes in the Federal Funds Target rate in [-1,1] window around FOMC meetings using rate changes in [-10, -1] window of 30-day Federal Funds Future (columns 1 and 3) and 30-day Eurodollar Future (column 2 and 4). Two sample windows used in the paper are considered one from January 1991 to December 2019, and the other from January 2009 to December 2019. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Panel A: High-stale Corporate Bond Funds

	$\Delta NAV_{i,[-10,-1]}$		$\Delta NAV_{i,[-1,2]}$		$\Delta NAV_{i,[-1,5]}$	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta FFuture_{[-10,-1]}$	−2.174	−1.487				
	(−1.517)	(−1.242)				
$\Delta FFTar_{[-1,1]}$			-0.386^{*}	-0.353^{*}	-0.635^{**}	-0.572^{**}
			(−1.799)	(−1.674)	(−2.278)	(−2.072)
$Controls^{F}_{i,t-1}$		✓		✓		✓
Fund FE	✓	✓	✓	✓	✓	✓
Observations	105,603	81,926	105,599	81,923	105,599	81,923
Adjusted R^2	0.011	0.015	0.002	0.013	0.004	0.012

Panel B: Low-stale Corporate Bond Funds

	$\Delta NAV_{i,[-10,-1]}$		$\Delta NAV_{i,[-1,2]}$		$\Delta NAV_{i,[-1,5]}$	
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta FFuture_{[-10,-1]}$	-5.323^{***}	-5.211^{***}				
	(−3.823)	(−3.730)				
$\Delta FFTar_{[-1,1]}$			-0.814^{**}	-0.782^{*}	−0.864	−0.788
			(−2.023)	(−1.921)	(−1.461)	(−1.305)
$Controls^{F}_{i,t}$		✓		✓		✓
Fund FE	✓	✓	✓	✓	✓	✓
Observations	71,159	57,846	71,158	57,846	71,158	57,846
Adjusted R^2	0.092	0.086	0.020	0.033	0.003	0.006

Table 3: NAV Changes around FOMC Meetings. This table presents how fund NAVs changes respond to market information around FOMC meetings for high-stale funds (panel A) versus low-stale funds (panel B). The funds with a higher-(lower-)than-median proportion of non-moving NAVs days in window [-20, -10] of each meeting are classified as high-(low-)stale funds. The dependent variables are the cumulative log NAV changes for fund share i in windows [-10,-1], [-1,2], and [-1,5] around FOMC meetings. We consider changes in the 30-day Federal Funds Future rate in windows [-10,-1] as information revealed before the FOMC meeting. $\Delta FFTar_{[-1,1]}$ is Changes in the Federal Funds Target rate in window [-1,1] around the FOMC meeting. $Controls^{F}_{i,t-1}$ are one-year lagged fund characteristics, including the total net asset in log scale, expense ratios, percentage of cash and government bond holding, high-yield fund indicator, and maturity. Each observation is weighted by previous year's fund TNA value. Standard errors are clustered at each FOMC meeting and the fund share level. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Panel A: Daily Evidence

	High-stale Funds				Low-stale Funds			
	ΔOutFlows$_{i,[-10,-1]}$		ΔOutFlows$_{i,[-5.-1]}$		ΔOutFlows$_{i,[-10,-1]}$		ΔOutFlows$_{i,[-5.-1]}$	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ΔFFTar$_{[-1,1]}$	0.970***	0.688**	0.787***	0.660***	0.793	0.684	0.585	0.538
	(2.880)	(2.208)	(3.304)	(3.454)	(1.652)	(1.535)	(1.590)	(1.546)
Controls$^F_{i,t-1}$		✓		✓		✓		✓
Fund FE	✓	✓	✓	✓	✓	✓	✓	✓
Observations	85,739	66,347	85,701	66,330	58,145	47,156	58,095	47,117
Adjusted R^2	0.081	0.103	0.077	0.098	0.087	0.085	0.068	0.072

Panel B: Monthly Evidence

	$OutFlow_{i,m}$(%) in Months with FOMC meetings			
	High-stale Funds		Low-stale Funds	
ΔFFTar$_m$	1.382***	1.137***	0.850**	0.702**
	(4.183)	(4.097)	(2.560)	(2.015)
ΔControls^M_m	✓	✓	✓	✓
Controls$^F_{i,t-1}$		✓		✓
Fund FE	✓	✓	✓	✓
Observations	161,311	135,253	161,308	132,722
Adjusted R^2	0.062	0.080	0.061	0.078

Table 4: Outflow-ΔFFTar relationship for Corporate Bond Mutual Funds. This table presents how fund flows respond to Federal Funds Target rate changes around FOMC meetings for high-stale funds versus low-stale funds. Panel A an B report results for daily data and monthly data, separately. In Panel A, the funds with a higher-(lower-)than-median proportion of non-moving NAVs days in window [-20, -10] of each meeting are classified as high-(low-)stale funds. The dependent variables are the cumulative fund outflows for fund share i in windows [-10,-1] and [-5,-1] around meetings. The key independent variable is the Federal Funds Target rate change around the window [-1,1] of each FOMC meeting. Controls$^F_{i,t-1}$ are one-year lagged fund characteristics, including the total net asset in log scale, expense ratios, percentage of cash and government bond holding, high-yield fund indicator, and maturity. Each observation is weighted by fund TNA value in day 10 before each meeting. Standard errors are clustered at each FOMC meeting and the fund share level. In Panel B, the funds with a higher-(lower-)than-top(bottom) tercile of proportion of non-moving NAVs days in the previous month are classified as high-(low-)stale funds. $OutFlow_{i,m}$ is the fund outflow for fund share i at month m. ΔFFTar$_m$ is the change in the Federal Fund Target rate in percentage point. Macro controls, ΔControls^M_m, include the change in the yield slope, the default spread, and the VIX index. Fund characteristics include past performance (Perf), past return and other fund-level controls in the daily analysis. Each observation is weighted by last month's fund TNA value. Standard errors are clustered at the fund share and month levels. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

	$OutFlow_{i,m}$(%) in Months with FOMC meetings					
	All		ΔFFTar$_m \geq 0$		ΔFFTar$_m \leq 0$	
	(1)	(2)	(3)	(4)	(5)	(6)
ΔFFTar$_m$	1.300***	1.148***	2.201***	1.771***	0.882**	0.811***
	(4.105)	(4.063)	(4.206)	(3.866)	(2.368)	(2.662)
ΔControls$_m^M$	✓	✓	✓	✓	✓	✓
Controls$_{i,t-1}^F$		✓		✓		✓
Fund FE	✓	✓	✓	✓	✓	✓
Observations	419,440	347,934	373,487	309,810	306,321	288,134
Adjusted R^2	0.038	0.070	0.039	0.068	0.035	0.071

Table 5: Monetary-policy-induced Fragility for Corporate Bond Mutual Funds (Monthly Evidence). This table reports tests for the effect of monetary policy changes on fund flows of corporate bond mutual funds from January 1992 to December 2019. We keep months with FOMC meetings only. Columns (1)-(2) use all samples, columns (3)-(4) focus on months with non-negative FFTar moves, and columns (5)-(6) focus on months with non-positive FFTar moves. $OutFlow_{i,m}$ is the fund outflow for fund share i at month m. ΔFFTar$_m$ is the change in the Federal Fund Target rate in percentage point. Macro controls, ΔControls$_m^M$, include the change in the yield slope, the default spread, and the VIX index. Fund characteristics include past performance (Perf), past return and other fund-level controls in the daily analysis of Table 4. Each observation is weighted by last month's fund TNA value. Coefficients (t-statistic) are reported in the shade (unshaded) rows. Standard errors are clustered at the fund share and month levels. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Panel A: Daily Evidence

	Illiquid Funds		Liquid Funds	
	ΔOutFlows$_{i,[-10,-1]}$ (1)	ΔOutFlows$_{i,[-5.-1]}$ (2)	ΔOutFlows$_{i,[-10,-1]}$ (3)	ΔOutFlows$_{i,[-5.-1]}$ (4)
ΔFFTar$_{[-1,1]}$	1.109**	1.052**	0.418	0.279
	(2.181)	(2.563)	(1.205)	(1.120)
Controls$^F_{i,t-1}$	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓
Observations	57,738	57,706	55,765	55,741
Adjusted R^2	.132	0.117	0.070	0.064

Panel B: Monthly Evidence

	$OutFlow_{i,m}$(%) in Months with FOMC meetings & ΔFFTar$_m \geq 0$			
	Liquid v.s. Illiquid Market Condition		Liquid v.s. Illiquid Funds	
	High^T VIX Months (1)	Low^T VIX Months (2)	Low^T CashBond Funds (3)	High^T CashBond Funds (4)
ΔFFTar$_m$	3.090***	0.481	2.689***	−0.125
	(3.530)	(0.951)	(4.013)	(−0.140)
ΔControls^M_m	✓	✓	✓	✓
Controls$^F_{i,t-1}$	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓
Observations	92,310	114,491	94,291	95,410
Adjusted R^2	0.103	0.118	0.119	0.082

Table 6: The Effect of Illiquidity on Monetary-policy-induced Fragility This table studies how fund illiquidity affects monetary-policy-induced Fragility around FOMC meetings. Panel A an B report results for daily data and monthly data, separately. In Panel A, for each FOMC meeting, we classify funds whose last year's percentage holding of liquid assets (cash and government bonds) is higher-(lower-)than-sample median as liquid (illiquid) funds. All other details are the same as Table 4. In Panel B, we keep months with FOMC meetings and non-negative Federal Fund Target rate moves. High^T equals 1 if the corresponding variable is above the top tercile, and 0 if it is below the bottom tercile over the sample period; Low^T is the opposite. All other details are the same as Table 4. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Panel A: Daily Evidence

	Sub-sample of *Illiquid* Funds			
	High-stale Funds		Low-stale Funds	
	ΔOutFlows$_{i,[-10,-1]}$	ΔOutFlows$_{i,[-5.-1]}$	ΔOutFlows$_{i,[-10,-1]}$	ΔOutFlows$_{i,[-5.-1]}$
	(1)	(2)	(3)	(4)
ΔFFTar$_{[-1,1]}$	0.809**	0.767***	1.781**	1.671**
	(1.998)	(2.779)	(2.093)	(2.118)
Controls$^F_{i,t-1}$	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓
Observations	37,289	37,278	20,449	20,428
Adjusted R^2	0.157	0.147	0.114	0.100

Panel B: Monthly Evidence

	Sub-sample of *Illiquid* Months		Sub-sample of *Illiquid* Funds	
	High-stale Funds	Low-stale Funds	High-stale Funds	Low-stale Funds
ΔFFTar$_m$	1.556**	2.733*	1.667*	2.054**
	(2.041)	(1.880)	(1.959)	(2.216)
ΔControls^M_m	✓	✓	✓	✓
Controls$^F_{i,t-1}$	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓
Observations	37,783	36,362	38,341	34,194
Adjusted R^2	0.203	0.216	0.221	0.203

Table 7: The Effect of Staleness on Monetary-policy-induced Fragility in Illiquid Funds (Periods). This table studies how fund staleness affects monetary-policy-induced fragility in illiquid funds or illiquid periods. Panel A an B report results for daily data and monthly data, separately. In Panel A, we keep funds with whose last year's percentage holding of liquid assets (cash and government bonds) is below the sample median (illiquid funds). We classify funds with a higher-(lower-)than-median proportion of non-moving NAVs days in window [-20, -10] of each meeting are classified as high-(low-)stale funds. All other details are the same as Table 4.

In Panel B, we keep months with FOMC meetings and non-negative Federal Fund Target rate moves. The sub-sample of illiquid months includes months with VIX index above the top tercile of the sample. The sub-sample of illiquid funds includes funds with the proportion of cash and government bond holding below the bottom tercile with each calendar year. We classify funds with a higher-(lower-)than-top(bottom) tercile of proportion of non-moving NAVs days in the previous month as high-(low-)stale funds. All other details are the same as Table 4. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Panel A: Liquid v.s. Illiquid Market Condition

	$OutFlow_{i,m}$(%) in Months with FOMC meetings		
	Low^T VIX (Liquid) Months	High^T VIX (Illiquid) Months	All Sample
	(1)	(2)	(3)
ΔFFTar$_m$	-0.308	2.252***	2.596***
	(-0.873)	(4.694)	(3.929)
ΔFFTar$_m \times \mathbb{1}$(Low^T FFTar$_m$)	2.181*	-3.269^{***}	-3.074^{***}
	(1.848)	(-4.831)	(-3.442)
ΔFFTar$_m \times \mathbb{1}$(Low^T VIX$_m$)			-2.708^{***}
			(-3.571)
ΔFFTar$_m \times \mathbb{1}$(Low^T FFTar$_m$) $\times \mathbb{1}$(Low^T VIX$_m$)			3.975***
			(3.250)
Controls	✓	✓	✓
Fund FE	✓	✓	✓
Observations	68,667	58,900	154,809
Adjusted R^2	0.189	0.223	0.125

Panel B: Liquid v.s. Illiquid Funds

	$OutFlow_{i,m}$(%) in Months with FOMC meetings		
	High^T CashBond (Liquid) Funds	Low^T CashBond (Illiquid) Funds	All Sample
	(1)	(2)	(3)
ΔFFTar$_m$	0.376	1.397**	1.382**
	(1.213)	(2.341)	(2.370)
ΔFFTar$_m \times \mathbb{1}$(Low^T FFTar$_m$)	1.693**	-1.946^{**}	-1.668^{**}
	(2.033)	(-2.558)	(-2.264)
ΔFFTar$_m \times \mathbb{1}$(High^T CashBond$_i$)			-0.902
			(-1.358)
ΔFFTar$_m \times \mathbb{1}$(Low^T FFTar$_m$) $\times \mathbb{1}$(High^T CashBond$_i$)			3.556***
			(2.988)
Controls	✓	✓	✓
Fund FE	✓	✓	✓
Observations	71,401	70,190	141,591
Adjusted R^2	0.154	0.175	0.149

Table 8: The Effect of Policy Environment on Monetary-policy-induced Fragility (Monthly Evidence) This table reports tests for monetary-policy-looseness-enhanced fragility in a liquid market for corporate bond mutual funds from January 1992 to December 2019. The market is liquid if the VIX index is below the sample average. $OutFlow_{i,m}$ is the fund outflow for fund share i at month t. We keep months with FOMC meetings and non-negative Federal Fund Target rate moves. High^T equals 1 if the corresponding variable is above the top tercile, and 0 if it is below the bottom tercile over the sample period; Low^T is the opposite. Controls include all macro controls and fund characteristics as in Table **??**, as all as their interactions with the indicator variable. Coefficients (t-statistic) are reported in the shade (unshaded) rows. Standard errors are clustered at the fund share and month levels. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Appendix

A A Model of Fund Run

In this section, we develop a model of runs for an open-ended bond mutual fund with monetary policy (interest rate) risk.[18] We first describe the model set-up, then identify the equilibrium conditions, and last conduct a comparative statics analysis.

A.1 The Setup

There are three dates: T_0, T_1 and T_2. There is “cash" without time-discounting. There is only one type of asset traded in the market, namely, the zero-coupon long-term bonds (“the bonds”) with face values 1 and maturity at T_2. To focus on the effect of interest rate risk, we assume the bond has no credit risk.

Monetary policy. Monetary policy in our model is summarized by three parameters, r, σ, and $\tilde{v}$. 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 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. 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. The realization of $\tilde{v}$, denoted as v, is decided by the central bank right before T_1. T_1 corresponds to the date of the FOMC meeting, at which the central bank publicly announces the new interest rate $r + \sigma v$.

Investors and a bond mutual fund. There is a continuum of risk-neutral investors. Each investor has one unit of cash invested in an open-ended bond mutual fund (“the fund”) and can redeem her capital from the fund right before T_1 or hold to T_2 to share the fund’s assets.[19]

The fund acts as an investment vehicle of the bonds. We assume that the fund invests all the cash received from investors in the bonds at T_0, buying $\frac{1}{p_0}$ units of the bonds at the initial 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.

[18] In this paper, we narrow monetary policy to interest rate management.

[19] 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 and redemption externality. Right before T_1, i.e., before the interest rate shock $\tilde{\nu}$ is announced, 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 $\mathcal{L}p_1$, where the exogenous liquidation discount factor, $\mathcal{L} \in [0, 1]$, reflects the liquidity of the bond market.[20]

The options granted to investors, who submit redemption notices right before T_1, allows them to withdraw at the NAV based on the market price of bond $\bar{p}_1$. When the price at the times of the bond sales p_1 at T_1 is below $\bar{p}_1$, the fund has to sell additional shares to pay the redemption proceeds. As a result, the fund assets remaining to share among the staying investors shrink, leading to strategic complementarities in investors' redemption decisions. This is the redemption externality generated by interest rate risk. The redemption externality is further magnified when the bond market becomes more illiquid (lower $\mathcal{L}$). We describe the redemption game and investors' payoffs in detail below.

The redemption game and investors' payoffs. Right before T_1, the interest rate shock is not announced by the central bank. Each investor observes a private signal about the shock ν and then individually decides whether to redeem her share or not. The information structure will be discussed formally in Section A.2. Redeeming investors have a claim to receive the 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.

The investors' payoff at T_2 depends 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 a 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

$$\frac{1}{p_0} \geq \lambda\frac{\bar{p}_1}{p_0} \times \frac{1}{\mathcal{L}p_1} \quad \Longleftrightarrow \quad \lambda \leq \frac{\mathcal{L}p_1}{\bar{p}_1}. \tag{A.1}$$

Table A.1 summarizes the payoff of fund investors at T_2. When $\lambda \leq \frac{\mathcal{L}p_1}{\bar{p}_1}$, 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 bonds, 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 $\frac{1}{p_0}\mathcal{L}p_1$ are shared and re-invested by λ redeeming investors, while a staying investor receives nothing at T_2.

The payoff of staying investors is plotted in Figure 6. It is immediate to see the redemption externality imposed by redeeming investors on the staying ones, and how it is magnified by bond

[20] The liquidation discount $\mathcal{L}$ stems from inventory cost of market maker, search costs in the over-the-counter market, and bargaining power of the counterparties.

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

Table A.1: The payoff of investors at T_2.

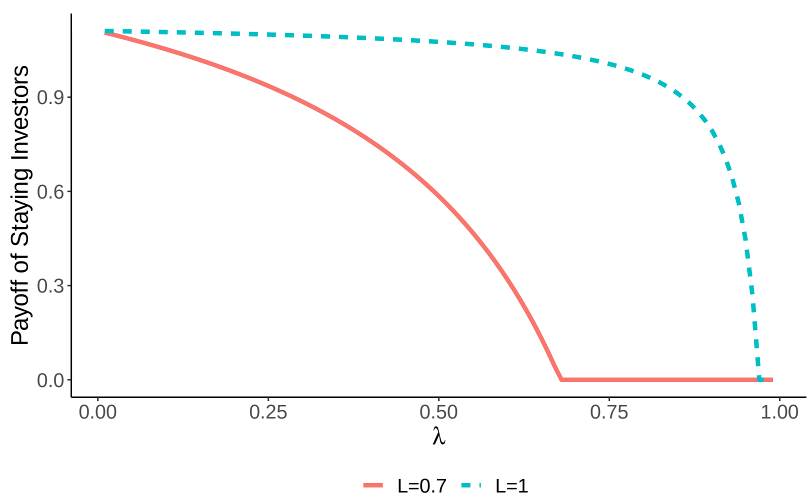


Figure 6: The payoff of staying investors at T_2.

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 higher rate and reach zero earlier. Importantly, the redemption externality exists even in a perfect liquid market where $\mathcal{L} = 1$, making our redemption externality fundamentally different from the one caused by bond illiquidity, see for example, Chen, Goldstein, and Jiang (2010); Goldstein, Jiang, and Ng (2017).

A.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 exist 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 full redemption on the bond mutual fund ("fund run"), which we interpret as the *fragility* of the bond fund.

A.2.1 Multiple equilibria under perfect signals

Suppose right before T_1, all investors receive perfect signals about the interest rate shock ν, 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

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

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,

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

In this region, staying is the dominant strategy, and hence, all investors staying is the only equilibrium.[21]

[21] 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, $\frac{\bar{p}_1}{p_0}\frac{1}{p_1}$.

Finally, there is a non-empty region with intermediate value of $v \in (\underline{v}, \bar{v})$ if $\mathcal{L} < 1$. In this region, multiple equilibria exist. All investors redeem in one equilibrium, and all of them stay in the other. To see this, it is useful to define the payoff difference between redeeming and staying for an investor as

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

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 $v \in [\underline{v}, \bar{v}]$.

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

Proof. See the Appendix B.1 □

A.2.2 Global game and fragility of bond fund

In order to compute the likelihood of the run on the fund and study the effect of monetary policy on it, we apply the global-game techniques and achieve a 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 v right before T_1, given by $s_i = v + \sigma_\varepsilon \varepsilon_i$, 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—there is a cutoff threshold v^* 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 0:

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

As common in the literature, our analysis focuses on the case where the noises in signals become arbitrarily close to zero. As $\sigma_\varepsilon \to 0$, investors observe the interest rate 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 shock v is above the threshold v^*. Moreover, as explained in details in Morris and Shin (2003), v^* can be characterized easily by using (A.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*

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

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

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

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

Proof. See the Appendix B.2 □

Proposition 1 delivers the first sharp empirical prediction on investors' equilibrium behavior—the larger the interest rate shock, the higher the likelihood of fund run. We call this monetary-policy-induced fragility. The Equation A.6 illustrates clearly the economic forces of such behavior. By re-writing (A.6), using the definition of the bond price for a given realized shock $p_1(v) = \frac{1}{1+r+\sigma v}$, 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

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

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 $\frac{1}{p_0} p_1(v)$. 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 $\bar{p}_1 > p_1(v)$, saying that investors, who essentially observe the true value of the bond, redeem the shares whenever the NAV per unit of the 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 v^* is pinned down, we can compute the ex-ante probability of the equilibrium in which all investors redeem, i.e., $\mathbb{P}(\tilde{v} > v^*)$. As in Chen, Goldstein, and Jiang (2010), we interpret this measure as the fragility of the fund.

A.3 Fragility in funds under different monetary policy environments

In this section, we study how fragility in bond mutual funds responds to different monetary policy environments and market liquidity conditions. The results of these analyses 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 impacts financial fragility in the bond fund. In our model, a lower current interest rate r represents a looser monetary policy environment and higher volatility σ of the interest rate shock proxies for higher uncertainty in 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 B.3. □

Corollary 1 contains predictions of the model. 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 monetary policy reinforce each other. Finally, bond 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 (A.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 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 v^* 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 the 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 prevent fragility. Put differently, as the market becomes more illiquid, the fragility concern from coordination risk becomes more critical and counteracts the fragility arising from the Jensen's effect associated with loose monetary policy environment, that is, $\frac{\partial \mathbb{P}(\tilde{v}>v^*)}{\partial(-r)}$ becomes less positive when $\mathcal{L}$ decreases.

A similar intuition applies to an increase in monetary policy uncertainty σ. The effect of Jensen's inequality becomes stronger with higher uncertainty, and hence, the bond fund is more fragile in a more volatile monetary policy environment. The effect is weakened as the bond market becomes illiquid because the fragility induced by illiquidity counteracts the fragility arising from high monetary policy uncertainty. The result that low-r and high-σ reinforce each other's impact also follows intuitively from Jensen's effect.

A.4 Extension: the effect of staleness in NAV on fragility

In the model, the NAV is completely stale, reflecting no information about the change in interest rate. In addition, fund investors have no benefits from investing and staying in the funds. Here we relax these two assumption and extend the model to study the effect of staleness on fragility of corporate bond funds.

We first define NAV as $NAV = s\bar{p}_1 + (1-s)p_1$ where $s \in (0,1)$ reflects staleness. The baseline model is the special case with $s = 1$. In addition, we assume that staying investors derives non-monetary utility ψ/p_0 at $T = 2$ if the fund is not liquidated. $\psi \in (0, \bar{\psi})$ captures the unmodelled benefits of owning a diversified bond portfolio. The upper bond ψ is ensures that investors would never redeem their shares.

Proposition 2 (Effect of staleness on fragility). *For given staleness $s \in (0,1)$ and benefits of staying in a liquid fund $\psi \in (0, \bar{\psi})$, the threshold v^* now satisfies*

$$\frac{1}{1+r+\sigma v^*} = p_1^* = NAV \times g(\mathcal{L}, \psi) \tag{A.9}$$

There exists a $\mathcal{L}(\psi) < 1$ such that staleness increases (decreases) fragility for $\mathcal{L} > (<) \mathcal{L}(\psi)$.

Proof. See the Appendix B.3. □

Proposition 2 shows that staleness in NAV increases fragility when liquidity is high enough and decrease otherwise. More specifically, staleness increases fragility when $p_1^* < NAV$ (or,

$g(\mathcal{L}, \psi) < 1$). In this case, $p_1^* < \bar{p}_1$ as $NAV = s\bar{p}_1 + (1-s)p_1$. Then, higher staleness s implies higher NAV, thus increasing investors' payoff from redemption. The intuition is that, when liquidity is high enough, investors are not concerned about redemption externality and redeem early only when there is a large enough profit $(NAV - p_1^*)$ from redemption. In the opposite case of staleness reducing fragility, investors start to redeem even when the updated price is still above the NAV $(p_1^* > NAV)$ because liquidity is low and the liquidation cost to be borne is high if investors stay. Thus, staleness reduces NAV and fragility.

Monetary Policy and Fragility in Corporate Bond Funds

Internet Appendix

A Additional Tables

	log(TNA)	Institution	Cash+Bond Holding	Expense Ratio	High Yield	Maturity
	(1)	(2)	(3)	(4)	(5)	(6)
High Staleness	−0.012	0.007	−1.785***	0.064*	−0.036***	−1.061***
	(−0.453)	(1.236)	(−7.362)	(1.929)	(−7.988)	(−15.410)
Year FE	✓	✓	✓	✓	✓	✓
Observations	36,989	37,042	36,818	35,294	37,042	33,946
Adjusted R^2	0.003	0.004	0.013	0.001	0.002	0.019
Note:						*p<0.1; **p<0.05; ***p<0.01

Table A.1: Fund Characteristics of High v.s. Low Stale Funds.

Panel A: Treasuries Bond Funds

	High Staleness			Low Staleness		
	$\Delta NAV_{i,[-10,-1]}$ (1)	$\Delta NAV_{i,[-1,2]}$ (2)	$\Delta NAV_{i,[-1,5]}$ (3)	$\Delta NAV_{i,[-10,-1]}$ (4)	$\Delta NAV_{i,[-1,2]}$ (5)	$\Delta NAV_{i,[-1,5]}$ (6)
$\Delta FFuture_{[-10,-1]}$	-1.962^{***}			-8.015^{***}		
	(−4.471)			(−2.974)		
$\Delta FFTar_{[-1,1]}$		−0.114	−0.171		−0.740	−0.989
		(−0.486)	(−0.596)		(−0.809)	(−0.736)
$Controls^F_{i,t-1}$	✓	✓	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓	✓	✓
Observations	2,216	2,216	2,216	1,553	1,553	1,553
Adjusted R^2	0.296	0.155	0.118	0.064	0.031	−0.019

Panel B: Equity Funds

	$\Delta NAV_{i,[-10,-1]}$ (1)	$\Delta NAV_{i,[-1,2]}$ (2)	$\Delta NAV_{i,[-1,5]}$ (3)
$\Delta FFuture_{[-10,-1]}$	−4.190		
	(−0.414)		
$\Delta FFTar_{[-1,1]}$		−3.855	−3.103
		(−1.553)	(−1.207)
$Controls^F_{i,t-1}$	✓	✓	✓
Fund FE	✓	✓	✓
Observations	604,176	604,124	604,124
Adjusted R^2	−0.009	0.012	0.006

Table A.2: NAV Changes around FOMC Meetings for Treasuries Bond Funds and Equity Funds. This table presents how fund NAVs changes respond to market information around FOMC meetings for treasuries bond funds (panel A) versus equity funds (panel B). The treasuries funds with a higher-(lower-)than-median proportion of non-moving NAVs days in window [-20, -10] of each meeting are classified as high-(low-) stale funds. We do not distinguish non-stale v.s. stable funds for equity funds, as around 66% observations of them have zero proportion of non-moving NAVs days before meetings. The dependent variables are the cumulative log NAV changes for fund share i in windows [-10,-1], [-1,2], and [-1,5] around FOMC meetings. We consider changes in the 30-day Federal Funds Future rate in windows [-10,-1] as information revealed before the FOMC meeting. $\Delta FFTar_{[-1,1]}$ is Changes in the Federal Funds Target rate in window [-1,1] around the FOMC meeting. $Controls^F_{i,t-1}$ are one-year lagged fund characteristics, including the total net asset in log scale, expense ratios, percentage of cash holding, high-yield fund indicator, and maturity (only for bond funds). Each observation is weighted by previous year's fund TNA value. Each observation is weighted by fund TNA value in day 10 before each meeting. Standard errors are clustered at each FOMC meeting and the fund share level. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Panel A: Treasuries Bond Funds

	High Staleness			Low Staleness		
	$\Delta\text{OutFlows}_{i,[-10,-1]}$	$\Delta\text{OutFlows}_{i,[-5,-1]}$	$\Delta\text{OutFlows}_{i,[1,5]}$	$\Delta\text{OutFlows}_{i,[-10,-1]}$	$\Delta\text{OutFlows}_{i,[-5,-1]}$	$\Delta\text{OutFlows}_{i,[1,5]}$
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\text{FFTar}_{[-1,1]}$	0.647	1.208	2.953	−1.143	0.907	−1.187
	(1.234)	(0.971)	(1.429)	(−0.464)	(0.507)	(−0.927)
$\text{Controls}^F_{i,t-1}$	✓	✓	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓	✓	✓
Observations	1,468	1,464	1,464	946	946	946
Adjusted R^2	−0.012	−0.017	0.020	−0.002	−0.014	0.014

Panel B: Equity Funds

	$\Delta\text{OutFlows}_{i,[-10,-1]}$	$\Delta\text{OutFlows}_{i,[-5,-1]}$	$\Delta\text{OutFlows}_{i,[1,5]}$
	(1)	(2)	(3)
$\Delta\text{FFTar}_{[-1,1]}$	0.500*	0.156	0.557
	(1.841)	(1.464)	(1.149)
$\text{Controls}^F_{i,t-1}$	✓	✓	✓
Fund FE	✓	✓	✓
Observations	485,964	485,681	485,176
Adjusted R^2	0.103	0.084	0.047

Table A.3: Fund Outflows around FOMC Meetings for Treasuries Bond Funds and Equity Funds. This table presents how fund flows respond to Federal Funds Target rate changes around FOMC meetings for treasuries bond funds (panel A) versus equity funds (panel B).The treasuries funds with a higher-(lower-)than-median proportion of non-moving NAVs days in window [-20, -10] of each meeting are classified as high-(low-) stale funds. We do not distinguish non-stale v.s. stable funds for equity funds, as around 66% observations of them have zero proportion of non-moving NAVs days before meetings. The dependent variables are the cumulative fund outflows for fund share i in windows [-10,-1], [-5,-1], and [1,5] around FOMC meetings. The key independent variable is the Federal Funds Target rate change around the window [-1,1] of each FOMC meeting. $\text{Controls}^F_{i,t-1}$ are one-year lagged fund characteristics, including the total net asset in log scale, expense ratios, percentage of cash holding, high-yield fund indicator, and maturity (only for bond funds). Each observation is weighted by fund TNA value in day 10 before each meeting. Standard errors are clustered at each FOMC meeting and the fund share level. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

Panel A: Daily Evidence

	Sub-sample of *Liquid* Funds			
	High-stale Funds		Low-stale Funds	
	ΔOutFlows$_{i,[-10,-1]}$	ΔOutFlows$_{i,[-5.-1]}$	ΔOutFlows$_{i,[-10,-1]}$	ΔOutFlows$_{i,[-5.-1]}$
	(1)	(2)	(3)	(4)
ΔFFTar$_{[-1,1]}$	0.555*	0.525***	0.335	0.165
	(1.838)	(2.692)	(0.915)	(0.607)
Controls$^F_{i,t-1}$	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓
Observations	29,058	29,052	26,707	26,689
Adjusted R^2	0.067	0.064	0.068	0.065

Panel B: Monthly Evidence

	Sub-sample of *Liquid* Months		Sub-sample of *Liquid* Funds	
	High-stale Funds	Low-stale Funds	High-stale Funds	Low-stale Funds
ΔFFTar$_m$	−0.881	−1.259	0.249	−1.680
	(−1.246)	(−1.500)	(0.283)	(−1.092)
ΔControls^M_m	✓	✓	✓	✓
Controls$^F_{i,t-1}$	✓	✓	✓	✓
Fund FE	✓	✓	✓	✓
Observations	43,836	43,022	34,776	39,541
Adjusted R^2	0.152	0.131	0.094	0.080

Table A.4: The Effect of Staleness on Monetary-policy-induced Fragility in Liquid Funds or Periods. This table studies how fund staleness affects monetary-policy-induced fragility in liquid funds or periods. Panel A an B report results for daily data and monthly data, separately. In Panel A, we keep funds with whose last year's percentage holding of liquid assets (cash and government bonds) is above the sample median (liquid funds). We classify funds with a higher-(lower-)than-median proportion of non-moving NAVs days in window [-20, -10] of each meeting are classified as high-(low-)stale funds. All other details are the same as Table 4. In Panel B, we keep months with FOMC meetings and non-negative Federal Fund Target rate moves. The sub-sample of illiquid months includes months with VIX index below the top tercile of the sample. The sub-sample of illiquid funds includes funds with the proportion of cash and government bond holding above the top tercile with each calendar year. We classify funds with a higher-(lower-)than-top(bottom) tercile of proportion of non-moving NAVs days in the previous month as high-(low-)stale funds. All other details are the same as Table 4. Coefficients (t-statistic) are reported in the shade (unshaded) rows. *, **, *** represent statistical significance at 10%, 5% and 1% level, respectively.

B Proofs

B.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 (A.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 (A.4) is

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

Moreover,

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

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 $\lambda > \hat{\lambda}$.

□

B.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 (2003) 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 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

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

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

$$
\mathcal{L}\left(\mathcal{L} + \mathcal{L}\log\left(\frac{1}{X\mathcal{L}}\right) - 1\right) - \left(\frac{1}{X} - \mathcal{L}\right)\log(1 - \mathcal{L}X) = 0. \qquad \text{(IA.A)}
$$

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 (A.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 (IA.A). 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

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

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

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

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

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 $\mathcal{L} \to 1$

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

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

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

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

B.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 derivative of v^* on r is

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

When $\mathcal{L} \to 1$, so does $g(\mathcal{L}) \to 1$. Then, we have $\frac{\partial v^*}{\partial r} < 0$, and

$$
\frac{\partial \mathbb{P}(v > v^*)}{\partial(-r)} = -f(v^*)\frac{\partial v^*}{\partial r} > 0.
$$

That is, fund fragility is higher in the low-interest-rate regime.

Proof for b The partial derivative of v^* on σ is

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

As $\mathcal{L} \to 1$, $g(\mathcal{L}) \to 1$. Then, we have

$$\frac{\partial \mathbb{P}(v > v^*)}{\partial \sigma} = -f(v^*)\frac{\partial v^*}{\partial \sigma} > 0.$$

That is, 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 derivative of v^* on r and σ is

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

Denote $Z = \frac{1}{1+r+\sigma\tilde{v}}$, we can derive

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

Hence,

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

The derivation of last inequality is 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 derivative 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 derivative 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

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

□

B.4 Proposition 2

Proof. The proof follows from the proof of Proposition 1 by replacing $\bar{p}_1$ with NAV. Then, by redefining $X = \frac{p_1^*}{NAV}$, the indifference condition that characterize v^* becomes

$$\mathcal{L} + \log(1-\mathcal{L}X)(1-\frac{1}{\mathcal{L}X}) - \log(\mathcal{L}X)\mathcal{L} = 1 + \psi\mathcal{L}X$$

It can be shown that for $\psi > 0$, there exists a $\mathcal{L}(\psi) < 1$ such that $X < 1 (> 1)$ if and only if $\mathcal{L} > (<)\mathcal{L}(\psi)$. Denote X as $g(\mathcal{L},\psi)$ and we have the equation A.9.

Finally, the effect of staleness on fragility follows from $sign(\frac{\partial\mathbb{P}(v>v^*)}{\partial s}) = sign(1 - g(\mathcal{L},\psi))$.

□