Does Mutual Fund Illiquidity Introduce Fragility into Asset Prices? Evidence from the Corporate Bond Market*

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Abstract

A growing literature shows that when a financial institution holds illiquid assets but provides liquid claims, its investors tend to run at the first sign of trouble, which generates fragility. We show that such fragility in financial institutions spills over into the assets they hold. Using a large sample of corporate bond mutual funds, we find that corporate bonds held primarily by illiquid funds tend to have fragile prices, with higher return volatility and lower liquidity. Moreover, the link between fund asset illiquidity and corporate bond price fragility is stronger when aggregate uncertainty is high and when the corporate bond fund sector experiences large redemptions. For corporate bonds whose investing funds hold more illiquid assets, we find that flows-driven mutual fund selling pressures are associated with a stronger price impact and subsequent return reversal.

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JEL Codes: G10, G12, G20, G23

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1 Introduction

Financial institutions play an important role in transforming illiquid assets into liquid claims, to satisfy the demand for liquidity by households. Despite the important economic function, a large literature has identified the risk of runs as an undesirable byproduct arising from liquidity transformation services provided privately by banks and shadow banks such as money market funds.[1] More recently, the literature has expanded into considering an increasingly important type of institutions, open-end mutual funds, which also play a role of liquidity transformation.[2] The new evidence echoes the key message from the earlier studies that the asset illiquidity of financial intermediaries renders them vulnerable to runs, which may create fragility to these institutions.

Does the fragility associated with asset illiquidity of financial institutions spill over to the asset market they invest in? In this paper, we address this question by studying the corporate bond market, which has experienced a large expansion in mutual fund ownership over the past decade. For instance, about 16,000 of corporate bonds were held by mutual funds in 2006; this number more than doubled as of 2016. Compared with traditional corporate bond investors such as insurance companies and pension funds, mutual funds are clearly different. First, they tend to turn over their portfolios more frequently. More importantly, they allow their investors to redeem shares on a daily basis while holding illiquid corporate bonds, which creates a liquidity mismatch. As a result, the expansion of mutual funds can have important effects on the pricing and liquidity of corporate bonds.

Motivated by theories that emphasize asset illiquidity in driving the adverse impact of liquidity transformation, we propose a new measure of corporate bond fragility, which is based on asset illiquidity levels of mutual funds holding that bond. This measure incorporates two pieces of information: how illiquid a fund's overall bond portfolio is, and how large this fund's position in a given bond is relative to other funds. Based on our measure, if a bond is

[1]See, e.g., Diamond and Dybvig (1983), Gorton and Pennacchi (1990), Gorton et al. (2010), Kacperczyk and Schnabl (2013), and Schmidt et al. (2016).

[2]See, e.g., Goldstein et al. (2017) and Chen et al. (2010).

held mainly by illiquid funds, the bond will receive a high score of fragility. The idea behind this measure is that, faced with negative shocks to mutual funds' bond holdings, investors in an illiquid bond fund have greater incentives to redeem their shares promptly; accordingly, when a bond is mainly held by illiquid funds, negative shocks can trigger larger outflows from funds holding that bond. Since outflows would ultimately lead mutual funds to sell their bond holdings, the bond could exhibit increasing fragility in prices, with higher return volatility and lower liquidity.

To test these predictions, we use a sample of 4,425 corporate bond mutual funds for the period of 2006 to 2016. We construct our fragility measure for corporate bonds based on a set of bond illiquidity proxies: the Amihud (2002) illiquidity ratio, the Imputed Round-trip Cost (IRC), and the effective bid-ask spread.

First, we find a strong and positive relation between bond fragility measures and subsequent return volatility. Recent literature documents excessive volatility of bond returns and shows that it is related to illiquidity of individual bonds (e.g. Bao and Pan, 2013). We find that the fragility measure is as important as the individual liquidity in forecasting bond volatility. For instance, when including both the individual liquidity and fragility in the regression, a one standard deviation increase in the Amihud illiquidity measure is associated with an increase of 1.89% in annualized bond return volatility during the subsequent quarter; and a one standard deviation increase in the Amihud-based fragility measure is associated with an increase of 1.55% in bond return volatility, which equals 18% of the median bond return volatility in our sample. Moreover, this effect of fragility measures on bond return volatility is robust to the inclusion of lagged return volatility, time fixed effects, bond fixed effects, and a variety of bond characteristics.

Second, we examine the relation between fragility measures and corporate bond illiquidity. Across the three proxies for bond illiquidity, we find that our fragility measures are robust predictors for future bond illiquidity, even after controlling for the bond's lagged illiquidity levels. For instance, a one standard deviation increase in the Amihud-based fragility measure is associated with an increase of 14.37 in the Amihud ratio during the subsequent quarter, about 40% of the median Amihud ratio in our sample.

These results support the notion that asset illiquidity of mutual funds generates fragility, which spills over into the assets they hold. There may be multiple transmission channels for this spillover effect. A natural channel is related to mutual fund fire sale pressures in the corporate bond market: when negative shocks alert investors to pull out money from illiquid corporate bond funds, the redemption-driven selling pressure can depress corporate bond prices and drive them away from their fundamental values temporarily, leading to higher return volatility, lower market liquidity.

To provide direct support to the mutual fund selling pressure channel, we follow Coval and Stafford (2007) and construct a measure of mutual funds' selling pressure based on realized fund trades conditional on large fund flows. We find that for bonds with higher fragility measures, the Coval-Stafford selling pressure variable is associated with a larger decline in contemporaneous bond returns and a stronger return reversal over the subsequent period.

We provide further evidence on the fire sale channel by exploiting time-series variation. First, we examine whether bond fragility measures have a stronger effect on bond price dynamics amid heightened macroeconomic uncertainty, proxied by a higher level of the VIX. Goldstein et al. (2017) show that the sensitivity of investor redemptions to a bond fund's underperformance increases both with the asset illiquidity of fund holdings and with the VIX; Jiang et al. (2017) further show that to meet investor redemptions amid high VIX, bond fund managers are more willing to liquidate corporate bonds, instead of tapping into their liquidity reserves. Together, the evidence in these papers implies a stronger spillover effect from the risk of runs faced by bond funds, to fire sale pressures, and eventually to more fragile bond prices, when VIX is high. As such, one would expect a stronger relation between fragility measures and bond price dynamics during high VIX periods.

In a similar vein, we investigate whether there is a stronger relation between mutual fund asset illiquidity and bond price fragility, when aggregate redemptions from the corporate bond fund sector are high. Intuitively, amid high aggregate redemptions, many corporate bond funds tend to liquidate their corporate bond holdings in concert, which can amplify the effects of fragility on bond price movements.

Our empirical tests show a stronger impact of fund asset illiquidity-induced fragility on future bond price movements, amid periods with higher VIX and large aggregate outflows. These results further support the fire-sale pressures as the underlying mechanism driving the spillover effect.

An alternative mechanism that may drive our main results is related to information asymmetry. It is possible that mutual funds self-select into holding bonds with varying degrees of information asymmetry. For instance, mutual funds specializing in security selection may hold a sizable fraction of bonds with a higher degree of information asymmetry.[3] In light of this, the higher asset illiquidity of investing funds may reflect higher information asymmetry of the bonds, which in turn have higher return volatility and less liquidity. To evaluate the validity of this mechanism, we examine the effect of fragility on the intertemporal return behavior. If our fund asset illiquidity-based fragility measure captures potential fire sale pressures due to mutual funds' demand for immediacy, one would expect, in the spirit of Grossman and Miller (1988), stronger return reversals for bonds with higher fragility. By contrast, if fund asset illiquidity-based fragility measure is driven by information asymmetry, one would not expect to observe such a link. Our empirical tests show a stronger return reversal for corporate bonds with higher fragility measures, which supports the fire sale pressure mechanism but not the asymmetry information story.

Furthermore, we consider an extension of our baseline fragility measure. Our fragility measure captures the average illiquidity of mutual funds holding a bond. However, Goldstein et al. (2017) show that bond funds holding more illiquid assets tend to experience disproportionately large outflows amid underperformance. It raises a natural question: does the

[3] The existing literature shows that lack of transparency in corporate accounting information disclosures can lead to stronger corporate bond illiquidity; such bonds are likely to exhibit higher return volatility.

shape of the distribution of the mutual fund illiquidity contain information about a bond's fragility? To address these questions, we construct another fragility measure capturing the skewness of asset illiquidity across mutual funds holding a bond. We find that after controlling for our baseline fragility measure, the skewness-based fragility contains incremental information about the bond's future illiquidity and price volatility.

Finally, we conduct a set of robustness tests by controlling for the level of mutual fund ownership, and the average cash holding level across investing funds. We also stratify our sample into subgroups based on low and high mutual fund ownership, and into investment-grade and speculative corporate bonds. Moreover, we perform the main analyses over different time periods. Overall, the fund asset illiquidity-based fragility consistently predicts bond volatility and illiquidity.

The rest of the paper is organized as follows. Section 2 discusses related literature. Section 3 offers a description for data set, summary statistics, and detailed explanations on the construction of fund asset illiquidity-based fragility measure. Section 4 shows the main results on the predicting power of fragility for bond volatility and illiquidity. Section 5 provide robustness analyses. We conclude in Section 6.

2 Related Literature

Our paper contributes to several strands of the literature. First, our paper builds on and extends the rapidly growing literature of runs on open-end mutual funds. Chen et al. (2010) and Goldstein et al. (2017) study how the illiquidity of mutual fund assets can exacerbate strategic complementarities among investors, which lead to investor runs on underperforming mutual funds. Schmidt et al. (2016) provide an interesting case for money market funds, which illustrates the important role of strategic complementarities in money markets. Against this backdrop, our paper is the first study that focuses on the feedback effects of the asset illiquidity of financial institutions on the underlying asset market.

Second, our paper is also related to a strand of literature that examines price impact on the corporate bonds stemming from mutual fund ownership. While there is a large amount of evidence in flow-induced price impact by equity mutual funds, the evidence is less clear-cut in the corporate bond market. Cai et al. (2019) study herding behavior among institutional investors in the corporate bond market; Jiang et al. (2017) and Choi and Shin (2018) examine the time-varying impact of flows-induced mutual funds sales; both studies show evidence of price impact when many institutions sell bonds at the same time. However, Choi et al. (2019) find no evidence for price impact in the corporate bond market due to mutual fund "fire sales." Our study is the first to emphasize the destablizing effect on the underlying bonds arising from asset illiquidity of mutual fund ownership, and quantify the impact of ownership illiquidity on volatility and liquidity of bond prices.

Third, our paper adds to the literature on excess return volatility for corporate bonds. Recent literature shows that structural models based on fundamentals cannot fully explain bond prices (eg. Huang and Huang (2012)). Bao and Pan (2013) find that the empirical volatilities of corporate bond are higher than implied by Merton model and the excess volatility is related to the illiquidity of the individual bonds. Our paper establishes a connection between the bond volatility and the asset illiquidity of its holders, which has additional explanatory power beyond bonds' own illiquidity. Thus it shows that the ownership structure of institutional investors also matters for bond volatility.

Finally, our paper helps expand the literature on corporate bond liquidity measures. Most existing bond liquidity measures are based on transactional data[4], which may fail to capture latent frictions and under-estimate the true illiquidity of corporate bonds, given that a significant fraction of corprpate bonds are not traded actively. Chernenko and Sunderam (2018) is a notable exception, where they follow a revelled preference approach, and use the sensitivity of corporate bond mutual fund cash holdings to fund flow volatilities as a indirect measure of bond illiquidity perceived by mutual funds. In the same vein, our paper

[4]See, for example, Roll (1984), Bao, Pan and Wang (2001), Amihud (2002), Dick-Nielsen, Feldhutter, and Lando (2012), and Bessembinder, Jacobsen, Maxwell, and Venkataraman (2017), among others.

also looks beyond bond transaction data, but use liquidity profile of mutual funds' corporate bond holdings to extract useful signals for the true illiquidity of the invested corporate bonds.

3 Data and Fragility Measures

3.1 Data and Sample Construction

Our study combines data from several sources, spanning a sample period from January 2006 to March 2016. First, we obtain data on mutual funds' holdings of fixed-income securities from Thomson Reuters Lipper eMAXX, as in Becker and Ivashina (2015) and Cai et al. (2019), among others. This data set is survivorship-bias free, and contains security-level fixed-income holdings at quarter-ends for institutional investors like mutual funds.

We focus on corporate bond mutual funds. Utilizing CUSIP-level holding information provided by eMAXX, we exclude funds with low corporate bond holdings. In particular, we exclude a fund if (i) its maximum holdings of corporate bonds across all quarters are less than \$1 million; or (ii) its corporate bond holdings never exceed 10% of its fixed-income holdings across all quarters. These filters eliminate funds that are categorized as fixed-income mutual funds but don't have substantial corporate bond holdings.[5] After applying these filters, we obtain 4425 eMAXX mutual funds with significant corporate bond holdings, with the top 1000 funds covering 93% in assets of the 4425 funds' total corporate holdings. To further supplement our data on mutual funds, we also obtain mutual fund characteristics such as asset under management (AUM) and cash holding composition from CRSP survivor-bias free mutual fund data. Following the prior literature, we aggregate the CRSP share-class level information to fund-level. After that, we manually match the two data sets based on fund names.[6]

[5]The amount of corporate bonds held by funds excluded by the two criteria makes up about 0.2% of the total mutual fund corporate bond holdings in the eMAXX data.

[6]To match to our eMAXX corporate bond fund sample, we focus on domestic corporate bond funds and domestic mixed funds from the CRSP database, excluding government fixed-income funds, municipal bond funds, and money market funds.

Among the 4425 corporate bond mutual funds in eMAXX, 2092 of them were successfully matched to CRSP mutual fund database. The top panel of Figure 1 shows the time series of total dollar value of corporate bond holdings by the eMAXX funds in our sample, and that by the matched funds. In particular, the total dollar amount of corporate bonds held by the matched funds accounts for over 80% of corporate bond holdings by the eMAXX fund group.

Next, we use the enhanced TRACE database to gather information about corporate bond transactions and prices. Applying standard filters in the literature for the TRACE data, we remove canceled and corrected trades, and exclude commission trades and inter-dealer trades. To mitigate the effect of large bid-ask bounce due to retail investors' tradings on the return calculation, we follow the recommendation by Bessembinder et al. (2008) and remove trades with less than $100,000 in notional amount. We supplement the enhanced TRACE data with Mergent's Fixed Income Securities Database (FISD), which provides extensive bond-specific information, including credit rating histories. We focus on fixed-rate bonds, excluding bonds that are puttable, convertible, perpetual, or exchangeable, and that have announced calls. We also exclude asset-backed issues, Yankees, Canadian, issues denominated in foreign currency, and issues offered globally.

Using the TRACE data, we calculate three sets of widely-used corporate bond liquidity measures: the "Amihud" measure gauges the price impact of a given trading size; the "IRC" computes the round trip transaction cost following Feldhütter (2012) and Dick-Nielsen et al. (2012); and the "Spread" is the same-bond-same-day effective spread proposed by Hong and Warga (2000), which is the average buy prices minus average sell prices of all transactions on the same day for the same bond. The calculation of these liquidity measures are detailed in Appendix A. It is worth noting that the higher these three measures are, the more illiquid the bond is. All three liquidity measures are winsorized at 1% and 99% levels.

We merge corporate bond information obtained from TRACE and FISD to that from eMAXX, based on bonds' 8-digit CUSIP. As shown in the bottom panel of Figure 1, over 82%

of corporate bond holdings in eMAXX are matched with trading information from TRACE and bond characteristics from FISD.[7]

3.2 Constructing the Measure of Corporate Bond Fragility

In this subsection, we describe the methodology to construct a "fragility" measure of a corporate bond based on its investing mutual funds' asset illiquidity. The intuition builds on the message from the previous literature: a mutual fund holding a substantial amount of illiquid bonds can be prone to large investor redemptions upon negative shocks, which in turn can lead the fund to liquidate its bond holdings. When a particular bond is held primarily by illiquid mutual funds, the "fragility" in individual funds is likely spilled over to the bond.

Therefore, we use a two-step procedure to construct the holdings-based bond fragility measure. First, we calculate the fund-level liquidity measure, which is the value-weighted average of bond liquidity measures within each fund. The weight used in this calculation is the dollar holding amount of each corporate bond by a mutual fund. In particular,

$$Fund\ Illiquidity_{j,t}^{type} = \frac{\sum_{i=1}^{I} Holding\ Amount_{j,i,t} \times Bond\ Illiquidity_{i,t}^{type}}{\sum_{i=1}^{I} Holding\ Amount_{j,i,t}}, \tag{3.1}$$

where $Bond\ Illiquidity_{i,t}^{type}$ is the Illiquidity measure of bond i in quarter t with type being either "Aminud", "IRC", or "Spread", $Holding\ Amount_{j,i,t}$ is the par amount of corporate bond i held by mutual fund j as of the end of quarter t. For example, if a mutual fund holds equal amount of two corporate bonds with "IRC" illiquidity measures being 1 and 1.6, the "IRC"-based fund illiquidity measure is 1.3. Therefore, these fund-level illiquidity measures reflect the overall liquidity condition of a mutual fund's corporate bond holdings.[8]

[7] Note that when a corporate bond is not traded at least once within a certain quarter, which happens in the corporate bond market, it dose not have any trading information from TRACE and therefore will not be matched to the eMAXX holding data.

[8] In an unreported analysis, we examine the characteristics of funds with relatively illiquid assets. We find that funds with more illiquid holdings tend to earn higher net-of-fee returns, have less portfolio turnover, charge a higher expense ratio, and experience higher return volatility over the next 2 years.

Second, we compute the bond-level fragility measure based on fund-level liquidity measures. In particular, we define

$$Fragility_{i,t}^{type} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Illiquidity_{j,t}^{type}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}}, \tag{3.2}$$

where $Fund\ Illiquidity_{j,t}^{type}$ is the liquidity measure of fund j in quarter t with type being either "Aminud", "IRC", or "Spread", as defined by equation (3.1). $Holding\ Amount_{j,i,t}$ is the par amount of corporate bond i held by mutual fund j at the end of quarter t. For each type of fund liquidity measure, a corresponding bond fragility measure is calculated.

Figure 2 illustrates the time trend of the three fragility measures defined in (3.2) over our sample period from 2006:Q1 to 2016:Q1. The time series are calculated by taking the cross-sectional mean in each quarter, weighted by the outstanding amount of each bond. As shown in Figure 2, the three bond-level fragility measures generally follow the same trend and all of them see dramatic spikes during the global financial crisis (2008:Q2 to 2009:Q3). The systematic increase of the fragility measures around the financial crisis period suggests that it is important to control for the time fixed effect in the regressions.

3.3 Summary Statistics

Panel A of Table 1 presents summary statistics of the variables in our sample, calculated based on bond-quarter observations.[9] An average corporate bond in our sample has an outstanding amount of $518 million, with time to maturity of about 8.7 years, a coupon rate of 6%, a credit rating of BBB,[10] and a turnover rate of 15% within a quarter. The average return (annualized) of the bond is 9%, and the standard deviation of annualized weekly returns within the quarter is 12%.

The average bonds illiquidity measure based on Amihud is 63% per million dollars, which

[9] A detailed list of variable definitions can be found in Appendix A.

[10] Bond rating is calculated as the average ratings from Moodys, S&P, and Fitch, ranging from 1 to 24, with 1 representing the highest rating (AAA) and 24 representing the lowest rating (D). 1-10 is the rating range for investment-grade bonds, and 11-24 is the rating range for high-yield bonds. A number rating of 9 corresponds to BBB for S&P and Fitch, and BAA2 or BAA for Moody's.

means with a median trade size of $25,000, the average price impact is 1.58%. The average illiquidity based on IRC and same-day bid-ask spreads are is 0.81%, and 1.31%, respectively. The distribution of bond illiquidity measures are all heavily right-skewed, represented by larger means compared to medians. Meanwhile, the bond's fragility measures calculated from its investing mutual funds' asset illiquidity levels are 40% per million dollars based on Amihud, 0.68 based on IRC, and 0.96 based on same-day bid-ask spreads.

As noted in Panel B of Table 1, the three illiquidity measures of corporate bonds (Amihud, IRC, and Spread) are reasonably correlated, with pair-wise correlations ranging from 0.36 to 0.61. In addition, bond illiquidity measures and holding-based fragility measures are positively correlated, with pair-wise correlations ranging from 0.32 to 0.57.

4 Main Empirical Results

In this section, we investigate whether a corporate bond's fragility induced by asset illiquidity of its investing mutual funds affects the bond's volatility and illiquidity. We also explore the potential mechanism of our findings by introducing mutual fund flows and flow-induced selling pressures to the regression models.

4.1 Baseline Results

4.1.1 Predicting Bond Return Volatility

The excess volatility of corporate bonds has attracted broad attention from both academia and regulators.[11] We hypothesize that the significant liquidity mismatch faced by open-end bond mutual funds, coupled with their increasing participation in the corporate bond

[11] Bao and Pan (2013) explored potential explanations from both firm fundamental and trading illiquidity perspectives. Bao et al. (2018) document a strong positive cross-sectional relation between corporate bond yield spreads and bond return volatilities. Bai et al. (2019) explore whether the distributional characteristics of corporate bond returns can predict cross-sectional differences in future bond returns, and find a significantly positive relation between volatility and corporate bond returns. Chung et al. (2019) examines the pricing of volatility risk and idiosyncratic volatility in the cross-section of corporate bond returns.

market, may cause excessive price movements for individual bonds.

As the baseline for our analyses, we conduct quarterly panel regression tests on individual bonds while controlling for time-fixed effects, as follows:

$$Bond\ Volatility_{i,t+1} = Fragility_{i,t}^{type} + Controls_{i,t} + \epsilon_{i,t+1}. \tag{4.1}$$

Bond return volatility is measured by the standard deviation of annualized weekly return over the next quarter, in decimal. A set of fund characteristics known to affect bond return volatility is controlled for, including bond illiquidity measures, proxied by the Amihud measure (in percent per $million), IRC (in percent), and effective bid-ask spreads (in percent).[12] Other control variables include turnover, credit rating, natural log of the outstanding amount of the bond in thousands of dollars, annualized quarterly returns, coupon rate, natural log of number of months until bond maturity, and stock volatility for the bond's corresponding company.

Table 2 shows several key results. First, Columns 1 to 3 show that the coefficients of bond fragility measures based on all three liquidity measures are significantly positive, even after controlling for the lagged value of the corresponding bond illiquidity measures themselves and other variables that were known to predict bond volatility. Second, the economic significance of the predicting power is also sizable. For instance, one standard deviation in increase in bond fragility based on $Fragility_{Amihud}$ is associated with an increase of $0.0007 \times 22.11 = 1.55\%$ in the annualized bond return volatility over the next quarter, about 20% of the median level of bond volatility. The economic significance of the impact on volatility by bond fragility is comparable to that by bond illiquidity: one standard deviation increase in Amihud is associated with an increase of $0.0002 \times 94.37 = 1.89\%$ in bond volatility.

[12] Our bond fragility measure, by construction, may reflect to some degree its corresponding illiquidity measure. In the extreme case where a corporate bond is held by only one mutual fund who happens to hold this one bond in its portfolio, the bond's fragility measure, by definition, will be the same as its liquidity measure. Such case, however, is very unlikely, as on average a mutual fund holds about 100-200 corporate bonds and a corporate bond is held by 50-80 mutual funds. To address any remaining concern, we control for the bond's own illiquidity measures in all regressions when fragility measures are used as an independent variable.

Third, the predicting power of fragility for bond return volatility survives the control for a bond fixed effect (Columns 4 to 6).[13] These results suggest that bond fragility arising from asset illiquidity of its investing funds further affect corporate bond volatility in a significant way thats beyond the usual mechanisms documented in the existing literature.

Moreover, other control variables are shown to impact bond volatility in a way consistent with the findings in the existing literature. For instance, the coefficients of various bond illiquidity measures are shown to be significantly positive, suggesting that illiquid bonds tend to experience higher future return volatility, consistent with trading friction being a contributing factor to the excess bond volatility (Bao and Pan, 2013). Bonds with lower turnover, worse credit ratings, lower outstanding volume, worse past performance, and longer time-to-maturity, appear to subsequently experience higher return volatility. Finally, bond volatility is also shown to be subject to spillovers from the equity trading, as the coefficients of lagged equity return volatilities are significantly positive.

4.1.2 Predicting Bond Illiquidity

Illiquidity is known to be substantial for corporate bonds, and is estimated to explain about 50% of the cross-sectional variations in investment grade credit spreads (Longstaff et al., 2005; Bao et al., 2011). In this section, we investigate whether our fragility measures help predict bond liquidity. Our Fragility measures are constructed by aggregating asset illiquidity scores over investing funds, where fund's illiquidity scores are based on the average illiquidity of corporate bonds held by these funds. Hence, we may expect an intrinsic link between Fragility and bond liquidity. Panel B of Table 1 shows pair-wise correlations between Fragility and corresponding liquidity measure ranging from 0.36 to 0.56. The modest level of correlation suggests that it would be interesting to explore whether our fragility measures, which capture both mutual fund ownership and investing fund's asset illiquidity levels, may shed additional

[13] To reduce collinearity concern, we drop Coupon rates, which typically are little changed through the life span of a bond, in the specification with bond fixed-effect, Columns 4-6. In an unreported test, we also examine an alternative specification by including bond's lagged volatility as a control variable and excluding bond fixed-effect. Our findings are robust to the alternative specification.

light on bond liquidity.

We conduct a quarterly panel regression relating bond liquidity to lagged fragility measures with time fixed effect, as follows:

$$Bond\ Liquidity_{i,t+1}^{type} = Fragility_{i,t}^{type} + Controls_{i,t} + \epsilon_{i,t+1} \tag{4.2}$$

The same set of bond characteristics in Equation (4.1) are included in the control set. Shown in Columns (1) to (3) of Table 3, there is a robust pattern of higher bond fragility leading to higher bond illiquidity over the next quarter. The economic significance of the impact on bond liquidity by fragility is notable. For instance, Column 1 shows that one standard deviation increase in $Fragility_{Amihud}$ is associated with an increase of $0.6497 \times 22.11 = 14.37$ in the Amihud measure over the next quarter, about half of the median illiquidity level.

4.2 Potential Mechanism

Our main results above support the notion that the asset illiquidity of mutual funds generates fragility, which spills over into the assets they hold. There may be multiple transmission channels for this spillover effect. This section provides a set of analyses to shed light on the plausible underlying mechanisms.

4.2.1 Fire Sale Pressures?

A natural transmission channel is related to mutual fund fire sale pressures in the corporate bond market: when negative shocks alert investors to pull out money from illiquid corporate bond funds, the redemption-driven selling pressure can depress corporate bond prices temporarily and drive them away from their fundamental values, leading to higher return volatility and lower market liquidity. To investigate whether fire sale pressure serves as the transmission channel for our main results, we conduct two sets of analyses.

First, we exploit the implication of mutual fund flow-induced trades on asset prices. The existing literature has documented evidence for the price impact of mutual fund flow-induced trades,[14] which point to a subsequent return reversal when the price pressure ebbs away. If our fragility measure reflects fire sale pressure, we would expect bonds with higher fragility to experience stronger return reversals.

To investigate along this line, we follow Coval and Stafford (2007) and construct a measure of trading pressure based on realized fund trades conditional on large fund flows:

$$Sell\ Pressure_{i,t} = \frac{\sum_{j=1}^{J}(Sell\ Amt_{j,i,t}|Flow_{j,t} < 10^{th}\ Pctl - Buy\ Amt_{j,i,t}|Flow_{j,t} > 90^{th}\ Pctl)}{Amount\ Outstanding_{i,t}}. \quad (4.3)$$

This measure captures the difference between purchases and sales of bonds by mutual funds that experience extreme inflows and outflows, with a large positive (negative) value indicating strong selling (buying) pressure. With it, we perform the following quarterly regression, relating an interaction term of bond fund flow-induced pressure with fragility variables to abnormal returns over the concurrent quarter and over the next 1^{st}, 2^{nd} and 3^{rd} month, as follows:

$$AbReturn_{i,t+k} = Sell\ Pressure_{i,t} \times Fragility_{i,t}^{type} + Sell\ Pressure_{i,t} + Controls_{i,t} + \epsilon_{i,t+1}, \quad k = 0, 1, 2, 3 \quad (4.4)$$

Abnormal return is the annualized return difference between bond i and the weighted average return of a bond portfolio, matched by maturity and bond rating at the beginning of each month. Note for $k = 0$, we use the contemporaneous quarterly returns as the dependent variable, and for $k = 1, 2$, and 3, we use the monthly return over the 1^{st} (2^{nd} or 3^{rd}) month following quarter t as the dependent variable. We add to the control set the lagged value of bond fragility, liquidity, and fund flow induced pressure. Time-fixed effect is controlled for. Under the fire sale pressure mechanism, we would expect a negative coefficient of the interaction term for the concurrent quarter return regression, and a positive coefficient for the future return regressions.

[14]See, for examples, Coval and Stafford (2007), Frazzini and Lamont (2008), and Jiang et al. (2017).

Columns (1) to (4) of Table 4 show that using Amihud-based fragility measure, we detect a stronger negative impact due to fire sale pressures for bonds with higher fragility: the coefficient of the interaction term of lagged fire sale pressure and fragility is negative for the concurrent quarter return regression, but turns significantly positive for up to the next two months.[15] Using IRC- and Bid-ask spread-based fragility measures, we find similar return reversal patterns, as in Columns (5)-(8) and (9)-(12), respectively. These results are consistent with our hypothesis that our fragility measure affects bond prices through a fire sale mechanism. As such, higher fragility is associated with a stronger return reversal pattern.[16]

Second, we exploit time variations in the way mutual fund asset illiquidity affects bond price fragility. When aggregate uncertainty rises and markets are under stress, the payoff of illiquid risky assets such as corporate bonds can become more volatile, and these assets may become more illiquid. All these may induce stronger first-mover advantages among bond mutual fund, which, in turn, may lead fund managers to sell illiquid corporate bonds more aggressively at times of stress, exacerbating negative impact due to liquidity mismatch. In light of this, we conjecture that the impact by fund asset illiquidity-induced fragility on bond volatility and illiquidity may be stronger amid uncertain and stressed market conditions. In the following, we adopt various ways to capture market stress and uncertainties.

We start by examining whether bond fragility leaves a stronger impact on bond price movements amid heightened macro-economic uncertainty, proxied by the level of VIX. Goldstein et al. (2017) show that the sensitivity of investor redemptions to a bond fund's underperformance increases with both the asset illiquidity of the fund's holdings and the levels of VIX; Jiang et al. (2017) further show that when meeting redemptions amid high VIX, corporate bond funds tend to sell illiquid corporate bonds more aggressively, and such selling

[15] To understand the magnitude of fire sale pressures on returns, take a bond whose Amihud is set to the mean level of 40.05. One unit increase in Pressures implies $-1.2137 + 00605 \times 40.05 = 1.2063\%$ higher abnormal return over the next month.

[16] For the sake of brevity, Table 4 reports regression results without including the large set of control variables in quarter t. When controlling for these variables as in Table 2-3, we obtain even stronger return-reversal results. These results are available upon requests.

pressures are shown to lead to temporary movements in corporate bond prices. The evidence, together, suggests a potentially stronger spillover effect from run risks faced by bond funds, to bond price fragility amid high VIX periods.

Using the within-quarter average level of CBOE volatility index (VIX) as a proxy for aggregate uncertainty and market stress, we conduct the following regression estimation:

$$Bond\ Volatility(Bond\ Liquidity^{type})_{i,t+1} = Fragility_{i,t}^{type} + Fragility_{i,t}^{type} \times VIX_t + Controls_{i,t} + \epsilon_{i,t+1} \quad (4.5)$$

Table 5 summarizes the results on the key variables, while all the control variables in Equation (4.1) are also included but not reported in the table for brevity. Overall, the predicting power of Fragility on bond volatility and illiquidity of the subsequent quarter generally remains, and such predicting power appears to be stronger when VIX is high. In particular, the interaction term of Fragility with VIX generally exhibits a significantly positive impact on bonds' future volatility and illiquidity.

Next, we investigate whether there may be stronger spillover from fund run risks and fire sale pressures to bond price fragility, when aggregate redemptions from the bond fund sector are high. Intuitively, when a fund manager tries to liquidate holdings to meet redemptions, he may face increasing challenges if other funds also experience outflows at the same time and are in the process of liquidating portfolio. This suggests an amplified negative impact of funds' asset illiquidity on bond price movements, amid increasing aggregate outflows. To test this hypothesis, we conduct the following regression estimation:

$$Bond\ Volatility(Bond\ Liquidity^{type})_{i,t+1} = Fragility_{i,t}^{type} + Fragility_{i,t}^{type} \times Agg\ Flow_t + Controls_{i,t} + \epsilon_{i,t+1} \quad (4.6)$$

Where *AggFlow* represents the aggregate corporate bond flows in our sample. Table 6 summarizes the results on the key variables, while all control variables in Equation (4.1) are also included but not reported in the table for brevity. Again, the predicting power of

Fragility on bond volatility and illiquidity of the subsequent quarter generally remains, and such predicting power appears to be stronger amid larger aggregate outflows, as evidenced by the negative and significant coefficient of the interaction term of Fragility with aggregate fund flows.

All told, both the flow-induced pressure analysis and time variation analysis lend support to the fire-sale pressure as an underlying mechanism driving the spillover effect.

4.2.2 Information Asymmetry?

Another potential mechanism that may drive our main results is related to information asymmetry. It is possible that mutual funds self-select into holding bonds with varying degrees of information asymmetry. For funds specializing in security picking, they may hold a sizable fraction in bonds with higher degree of information asymmetry. The existing literature shows that information asymmetry leads to stronger illiquidity among the underlying corporate bonds.[17] In light of this, the asset illiquidity of investing funds may be reflecting the information asymmetry conditions of the traded bonds, and the latter is known to impact bond volatility and illiquidity.

To evaluate the validity of this mechanism, we examine the effect of fund asset illiquidity-induced fragility on intertemporal return behaviors. Specifically, we examine the autocorrelations of monthly returns. If bonds with higher values of the fragility measure tend to be held by informed investors, then their price changes will more likely be driven by informed trades. Since market prices will only partially and gradually reflect the private information, there is likely a return continuation in the next period (e.g., Kyle (1985)). Under the information asymmetry mechanism, we would expect a stronger return continuation pattern among bonds with higher fund asset illiquidity. In contrast, if bond fragility reflects fire sale pressure due to investing funds' demand for immediacy, in the spirit of Grossman and Miller (1988), we would expect a stronger return reversal among bonds with higher fragility.

[17] See Bao and Pan (2013), Fecht et al. (2014), and Bai et al. (2019).

Based on this, we set up our test using a quarterly panel regression, relating an interaction term of bond abnormal monthly return with fragility variables to future abnormal returns over the next 1^{st}, 2^{nd} and 3^{rd} month, as follows:

$$AbReturn_{i,t+k} = AbReturn_{i,t} \times Fragility_{i,t}^{type} + AbReturn_{i,t} + \epsilon_{i,t+1} \qquad k = 1, 2, 3. \quad (4.7)$$

We add to the control set the lagged value of bond fragility, liquidity, and return, as well as interaction terms of bond returns with its liquidity. Time-fixed effect is controlled for. If the transmission channel is through information asymmetry, the coefficient of the interaction term is expected to be either zero or positive; but if the transmission channel is due to fire sale pressures arising from fund liquidity mismatch, such effect would be temporary, hence the coefficient of the interaction term is expected to be negative.

Columns (1) to (3) of Table 7 show that using Amihud-based fragility measure, we detect a return reversal pattern for bonds with higher fragility: the coefficient of the interaction term of lagged bond return and fragility is significantly negative for up to the next two months. Using IRC- and Bid-ask spread-based fragility measures, we find similar return reversal patterns, as in Columns (4)-(6) and (7)-(9), respectively.

The results indicate a stronger return reversal for corporate bonds with higher fragility, suggesting that fund asset illiquidity-induced fragility does not appear to have a lasting impact on the underlying asset returns, but just amplify the temporary price pressure in the corporate bond market. These results are consistent with a fire sale pressure mechanism but not the information asymmetry story.

4.3 Extension: Skewness in Asset Illiquidity across Investing Mutual Funds

We construct our Fragility measure under the premise that the adverse impact arising from mutual fund liquidity transformation is affected by fund's asset illiquidity in a linear fashion. Under this assumption, our fragility measure is designed to focus on the average level of asset illiquidity across funds holding the bond. Goldstein et al. (2017), however, show that bond funds holding more illiquid assets tend to experience disproportionately large outflows amid underperformance. Hence, it is possible that for funds with extremely illiquid asset holdings, even a small negative shock to its performance could trigger a large bout of investor redemption, which may lead to amplified adverse impact on the underlying securities. Thus, not only the average level of asset illiquidity of all funds holding a bond affects bond fragility, but also whether the bond is held by some extremely illiquid funds may matter. In light of this, we design another measure to capture the fat-tailness in the liquidity profiles of the mutual funds that hold a bond. In particular, we focus on the skewness of asset illiquidity across investing funds, as follows:

$$Skewness_{i,t}^{type} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times (Fund\ Illiquidity_{j,t}^{type} - Fragility_{i,t}^{type})^3}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}} \quad (4.8)$$

where $Fund\ Illiquidity_{j,t}^{type}$ is the liquidity measure of fund j in quarter t with type being either "Aminud", "IRC", or "Spread", $Holding\ Amount_{j,i,t}$ is the par amount of corporate bond i held by mutual fund j at the end of quarter t, and $Fragility_{i,t}^{type}$ is the average asset illiquidity of all the mutual funds holding bond i, as defined by Equation (3.2). Note that in this skewness measure, we take out the mean effect, because we are interested in the incremental effect purely due to the fat-tailness in mutual fund asset illiquidity distribution.

We add the Skewness measure to our baseline specifications, and report the results in Table 8. We find that the Skewness in asset illiquidity across investing funds has significant incremental forecasting power for future bond volatility and illiquidity. The Skewness measure is statistically significant throughout all specifications. The results suggest that the distribution of asset illiquidity across investing funds affects the pricing of the underlying security in a complex way: not only the average level of asset illiquidity across the holders, but also the fat-tailedness in the distribution, may lead to adverse impact on the underlying bonds.

5 Robustness

In this section, we conduct analyses to ensure that the impact of fragility on bond volatility and illiquidity survives the controls for the level of mutual fund ownership and the cash holding level of investing funds, and the impact persists across the credit rating spectrum and over different periods.

5.1 Controlling for the Level of Mutual Fund Ownership

Our bond fragility measure reflects potential adverse impact stemming from mutual fund ownership. Yet, it goes above and beyond the simple aggregation of mutual fund ownership, and emphasizes the aspect of negative externality induced by mutual fund liquidity mismatch. Our bond fragility measure is effectively a weighted average of asset illiquidity across the bonds investing funds, with the weights commensurating with funds' relative presence, out of all investing funds, in the bond. One potential caveat is that our Fragility measure does not distinguish between bonds with high and low mutual fund ownership: by our measure, a bond with 50% mutual fund ownership can have the same degree of fragility as a bond with 5% mutual fund ownership. To see whether the impact of bond fragility persists after controlling for levels of mutual fund ownership, we conduct two sets of test.

First, we control for the lagged bond mutual fund ownership to Equations (4.1) and (4.2), as follows:

$$Bond\ Volatility(Bond\ Liquidity^{type})_{i,t+1} =$$
$$Fragility_{i,t}^{type} + MF\ Ownership_{i,t} + Controls_{i,t} + \epsilon_{i,t+1} \quad (5.1)$$

The results on the key variables are summarized in Table 9, while all control variables in Equation (4.1) are also included but not reported in the table for brevity. Panel A shows a significantly negative association between mutual fund ownership and subsequent bond return volatility, possibly due to mutual fund's preference for holding more liquid bonds. In addition, the predicting power of bond fragility on subsequent return volatility remains: both the magnitude and the significance levels of the coefficients have changed little, compared with the baseline case in Table 2. The economic impact on bond volatility by fragility is comparable to that by mutual fund ownership. In particular, Column 1 shows that one standard deviation increase in $Fragility_{Amihud}$ is associated with $0.0006 \times 22.11 = 1.3\%$ increase in bond volatilities over the subsequent quarter, about 15% of the median volatility level, while one standard deviation increase in mutual fund ownership is associated with $0.117 \times 0.15 = 1.8\%$ decrease in bond volatility, about 20% of the median volatility level.

Panels B shows that the predicting power of bond fragility on illiquidity remains, with the magnitude and the statistical significance of the coefficients barely changed compared to the baseline cases in Table 3. Moreover, higher mutual fund ownership is also shown to be associated with lower bond illiquidity over the next quarter.

Alternatively, we conduct subsample analysis, separating bonds into high and low mutual fund ownership groups, depending on whether a bond's mutual fund ownership is above or below the cross-sectional median. Results in Internet Appendix Table A1 show that the fragility measure continues to predict bond volatility for both subsamples. However, the predictive power of bond fragility for volatility is much stronger for those with high bond fund ownership. Take $Fragility_{Amihud}$ measure as an example, Panel A shows a coefficient of 0.0009 for the high mutual fund ownership sample, as compared to a coefficient of 0.0003 for the low mutual fund ownership sample. Similar patterns are observed in Panels B. The bigger magnitude for the high mutual fund ownership sample is consistent with mutual funds playing important roles in driving fragility of the corporate bond market.

The results, taken together, suggest that while participation by open-ended mutual funds in the corporate bond markets, on average, tend to attenuate volatility and illiquidity of the underlying assets, funds holding illiquid assets may introduce fragility to the underlying bond prices, which, in turn, leads to increases in bond volatility and illiquidity.

5.2 Controlling for the Level of Mutual Fund Cash Holdings

The basic notion in our paper is that bond fragility can arise from adverse impact stemming from investing funds' liquidity mismatch. We proxies the extent of mutual fund liquidity mismatch by focusing on the average illiquidity levels of their corporate bond holdings: the more illiquid funds' corporate bond holdings are, the more acute the liquidity mismatch concern and the stronger the adverse impact. Granted that our current fragility is an imperfect way to capture the overall extent of liquidity mismatch: when fund managers face outflows, they can first resort to cash holdings to meet the redemption needs, which may alleviate pressures due to liquidity mismatch. Hence, it is useful to investigate whether our fragility measure has additional predictive power for bond volatility, illiquidity and downside risk, after controlling for cash holdings of the investing funds. To that end, we construct a bond-level MF_{Cash} measure by aggregating cash holdings across investing funds, with weights commensurating with funds' relative presence among all investing funds in the bond:

$$MF\ Cash_{i,t} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Cash_{j,t}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}}. \quad (5.2)$$

We then add the MF_{Cash} measure to Equation (4.1)-(4.2) as follows:

$$Bond\ Volatility(Bond\ Liquidity^{type})_{i,t+1} = Fragility_{i,t}^{type} + MF\ Cash_{i,t} + Controls_{i,t} + \epsilon_{i,t+1} \quad (5.3)$$

Table 10 shows the results on the key variables, while all control variables in Equation

(4.1) are also included but not reported in the table for brevity. Three points emerged worth highlighting. First, higher levels of cash holding by investing funds are generally associated with lower subsequent bond return volatility and illiquidity, although the relation is not robust: in some specifications, the coefficient of MF_{Cash} is not statistically different from zero, and in some other specifications, the signs are even flipped. Second, our fragility measure continues to predict bond return volatility and illiquidity in most specifications: both the magnitude and the significance levels of the coefficients have changed little, compared with the baseline case in Table 2 and Table 3. Third, the economic impact by our fragility measure on bond volatility and illiquidity is much stronger than that by the aggregate mutual fund cash holding level. For instance, Column 1 of Panel A shows that one standard deviation increase in $Fragility_{Amihud}$ is associated with 0.0157 (i.e.0.0007×22.11) increase in bond volatilities over the subsequent quarter, or 17% of the median volatility level, while one standard deviation increase in the average cash holding by investing funds ownership is associated with 0.0014 (i.e.0.0005×2.74) decrease in bond volatility, 2% of the median volatility level.

Overall, our analysis suggests that adverse impact associated with mutual fund illiquid asset holdings is not offset by funds' cash holdings, and asset illiquidity-induced fragility continues to affect underlying bond price movements. This finding is consistent with Chernenko and Sunderam (2016), who provide evidence that mutual funds' cash holdings are not large enough to fully mitigate price impact externalities created by the liquidity transformation they engage in.

5.3 Subsample Analysis

5.3.1 Subsamples for High-Yield and Investment Grade Bonds

The literature shows that bonds with poor credit ratings are more vulnerable to fire sales,[18] suggesting a potentially more prominent impact by fragility on bond price movements in

[18] See, for example, Dick-Nielsen et al. (2012) and Friewald et al. (2013).

this cohort. In this section, we separately examine the impact of fragility for investment grade and high yield bonds. Bond rating is based on the average ratings from Moodys, S&P, and Fitch, ranging from 1 to 24, with 1 representing the highest rating (AAA) and 24 representing the lowest rating (D). Bonds rated between 1 and 10 are put in the investment-grade sample, and those rated between 11 and 24 in the high-yield sample. Results in the Internet Appendix Table A2 show that while our fragility measure significantly predict future bond volatility, liquidity and downside risk for bonds with different credit ratings, the economic magnitude of such impact is generally higher among high-yield bonds. The results corroborate our conjecture that fragility may play a more visible role affecting price movements among bonds with lower credit ratings.

5.3.2 Sub-period Results

Corporate bond markets have experienced radical changes over the past two decades. In response to the 2007-2009 financial crisis, central banks engaged in quantitative easing to stimulate economic growth. The accommodative monetary policy has led to a low interest rate environment, and spurred robust corporate bond issuance and increased outstanding volume. According to Securities Industry and Financial Markets Association (SIFMA), the outstanding amount of corporate bonds increased from about $5 trillion at 2006, the beginning of our sample period, to about $9 trillion at 2016, the end of our sample period.[19] In the meanwhile, non-traditional investors, such as mutual funds and ETFs, has acquired a bigger market share: based on corporate bond holdings by eMaxx funds in our merged sample, the total dollar amount of corporate bonds held by mutual funds was about half trillion in 2006Q1, and rose to $1.7 trillion by 2016Q1. Furthermore, regulatory changes took place following the recent crisis, including the Volcker Rule, which was enacted as part of the 2010 Dodd-Frank Wall Street Reform and Consumer Protection Act. While intended to limit banks' risk taking behaviors by putting a ban on banks' certain proprietary trading, Volcker

[19] See: https://www.sifma.org/resources/research/fixed-income-chart/.

Rule was also perceived by some critics as discouraging banks-affiliated dealer's market making activities, and hence diminishing corporate bond market liquidity and leading up to increased volatility. As such, the impact of mutual fund-induced fragility on corporate bond market can change over time.

In this subsection, we conduct subsample analyses, including pre-crisis (2006Q1–2007Q2), crisis (2007Q3–2009Q2) and post-crisis (2009Q3–2016Q1). For the post-crisis period, we conduct subsample analyses for periods of pre-Volker Rule (2009Q3–2014Q1) and post-Volcker Rule (2014Q2–2016Q1).

The results for the subsample analyses are reported in Internet Appendix Table A3 and Table A4. Overall, we find that the impacts of fragility on bond volatility and illiquidity persists over different phrases of market and regulatory developments. We find that the impacts of funds' asset illiquidity on bond volatility and illiquidity increase during the financial crisis from the pre-crisis period and remain high after the crisis. Interestingly, when we focus on the post-crisis period, we find that the fragility measure generally has a stronger predicting power after Volker Rule is implemented.

6 Conclusion

Our study builds on the growing literature on investor runs, which shows that when a financial institution holds illiquid assets but provides liquid claims, its investors tend to run at the first sign of trouble, which generates fragility. We propose a novel measure of bond fragility that captures the asset illiquidity of the bond's open-end mutual fund owners, who are subject to the risk of runs. Applying it to the corporate bond market from 2006–2016, we find that corporate bonds held primarily by illiquid funds tend to have fragile prices, with higher volatility and less liquidity.

To shed light on the source of fragility, we consider whether mutual fund selling pressures drive the observed relations. Following Coval and Stafford (2007), we construct a measure of selling pressure based on realized fund trades conditional on large fund flows. We find that for bonds with a high measure of fragility, the Coval-Stafford selling pressure variable has a stronger depressing effect on contemporaneous bond returns and predicts a larger return reversal. This result provides direct support to the mutual fund selling pressure channel.

We also exploit time-variation in the strength of the link between funds' asset illiquidity and corporate bond price fragility. First, the literature shows when aggregate uncertainty is high, investor redemptions tend to be more sensitive to the underperformance of corporate bond funds, and fund managers have a stronger tendency to sell corporate bonds. As a result, the relation between fund asset illiquidity and bond price fragility should be higher when uncertainty is high. Our tests show that when aggregate uncertainty rises, the price volatility and illiquidity are especially high for corporate bonds with a high fragility measure. Second, when aggregate investor redemptions from the corporate fund sector are high, many funds tend to liquidate their corporate bond holdings in concert, which can amplify the negative impact of bond fragility on bond price movements. We also find empirical support for this prediction. These results support the notion that the selling pressure from mutual funds contributes to the relation between fund asset illiquidity and bond price fragility.

In a nut shell, our results indicate that the fragility in financial institutions spills over into the assets they hold. We view our study as providing an interesting case that illustrates the relation between the liquidity of asset managers and the behavior of asset prices. It would be fruitful to extend the research to other asset classes to fully understand the relation.

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Appendix A Variable Definition

Variable Name	Definition
Fragility_Amihud	Bond-level fragility measure defined in Equation (3.1) and Equation (3.2)
Fragility_IRC	Bond-level fragility measure defined in Equation(3.1) and Equation (3.2)
Fragility_Spread	Bond-level fragility measure defined in Equation (3.1) and Equation (3.2)
Amihud (% per $million)	Quarterly Amihud illiquidity measure for a bond. First, we remove a trade if its price change is more than 20% from the previous trade within the same day. Then, we compute per transaction the Amihud measure as absolute value of return divided by the trading volume, then average across all trades of a bond within a quarter. We require at least 2 trades per quarter to report the measure. We winsorize the variable at the top and bottom 1% level.
IRC (%)	Quarterly Imputed Roundtrip Costs (IRC) calculated following Dick-Nielsen et al. (2012). We winsorize the variable at the top and bottom 1% level.
Spread (%)	Same-bond-same-day Effective Bid-Ask Spread calculated following Hong and Warga (2000), which equals the average buy prices minus the average sell prices of all transactions on the same day and same bond. We first calculate the measure for each bond each day, then average for each bond for all days within a quarter. We winsorize the variable at the top and bottom 1% level.
Turnover (%)	Total trading volume for a bond during a quarter divided by the amount outstanding at the prior quarter end. We winsorize the variable at the top and bottom 1% level.
Return	Annualized weekly return averaged within the quarter, in decimal. Weekly bond returns are calculated following Gebhardt et al. (2005): $$r_t = \frac{(P_t + AI_t) + C_t - (P_{t-1} + AI_{t-1})}{P_{t-1} + AI_{t-1}}, \quad \text{(A.1)}$$ where P_t is the transaction price at time t, AI_t is accrued interest, which is calculated as Coupon payment $\times$ days since last payment / days between consecutive coupon payments, and C_t is the coupon payment at time t, if any. The weekly return is winsorized at top and bottom 0.5% level.
Return_SD	Standard deviation of annualized weekly bond returns calculated over the quarter, in decimal.
Rating	Bond rating is calculated as the average ratings from Moody's, S&P, and Fitch, ranging from 1 to 24, with 1 representing the highest rating (AAA) and 24 representing the lowest rating (D). 1-10 is the rating range for investment-grade bonds, and 11-24 is the rating range for high-yield bonds.
Size	Amount outstanding of the bond, measured in thousands.
Maturity	Number of months until bond maturity, measured at the beginning of the quarter, winsorized at the top and bottom 1% level.
Coupon	Coupon rate of the fixed rate bonds, in decimal.
Stock_Vol	Stock volatility, which is calculated as the standard deviation of the daily stock returns (not annualized) of the bond's corresponding company during a quarter, in decimal. We winsorize the variable at the top and bottom 1% level.

Skewness_Amihud	For a given bond, the holding-amount-weighted skewness of its mutual fund holders' (il)liquidity measures, as defined in Equation (3.1) and Equation (4.8)
Skewness_IRC	For a given bond, the holding-amount-weighted skewness of its mutual fund holders' (il)liquidity measures, as defined in Equation (3.1) and Equation (4.8)
Skewness_Spread	For a given bond, the holding-amount-weighted skewness of its mutual fund holders' (il)liquidity measures, as defined in Equation (3.1) and Equation (4.8)
MF_Ownership	Mutual funds' holding share of a certain bond, in decimal with range of 0-1.
MF_Cash (%)	Bond-level mutual fund cash holding measure defined as: $$MF\ Cash_{i,t} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Cash_{j,t}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}},$$ where $Holding\ Amount_{j,i,t}$ is the par amount of corporate bond i held by mutual fund j as of the end of quarter t, and $Fund\ Cash_{j,t}$ is the cash holding of fund j (in percent) in quarter t. To mitigate the effects of misreporting, we follow prior literature and winsorize funds' cash holding to the range 0-20 (i.e., replacing cash holding with 20 when it is over that upper limit and setting cash holding to zero when it is negative.)
Sell_Pressure	We follow Coval and Stafford (2007) to construct a bond-level selling pressure measure, based on realized mutual fund trades conditional on large fund flows: $$Sell\ Pressure_{i,t} = \frac{\sum_{j=1}^{J}(Sell\ Amt_{j,i,t} \mid Flow_{j,t} < 10^{th}\ Pctl - Buy\ Amt_{j,i,t} \mid Flow_{j,t} > 90^{th}\ Pctl)}{Amount\ Outstanding_{i,t}},$$ where $Sell\ Amt_{j,i,t}$ is the par amount of corporate bond i sold by mutual fund j in quarter t (equal to zero if there's no selling), $Buy\ Amt_{j,i,t}$ is the par amount of corporate bond i purchased by mutual fund j in quarter t (equal to zero if there's no buying). $Flow_{j,t}$ is the quarterly percentage flow of fund j in quarter t, adjusted for fund returns. $Amount\ Outstanding_{i,t}$ is the outstanding amount of corporate bond i as of the end of quarter t. This selling pressure measure is winsorized at top and bottom 1% level.

Figure 1: **Data Matching**

This figure shows matching results between eMAXX, CRSP, and TRACE. The top panel shows corporate bond holdings in eMAXX that are sucessfully matched to CRSP (by matching mutual fund name). The bottom panel shows corporate bond holdings in eMAXX that are successfully matched to TRACE (by matching bond CUSIP).

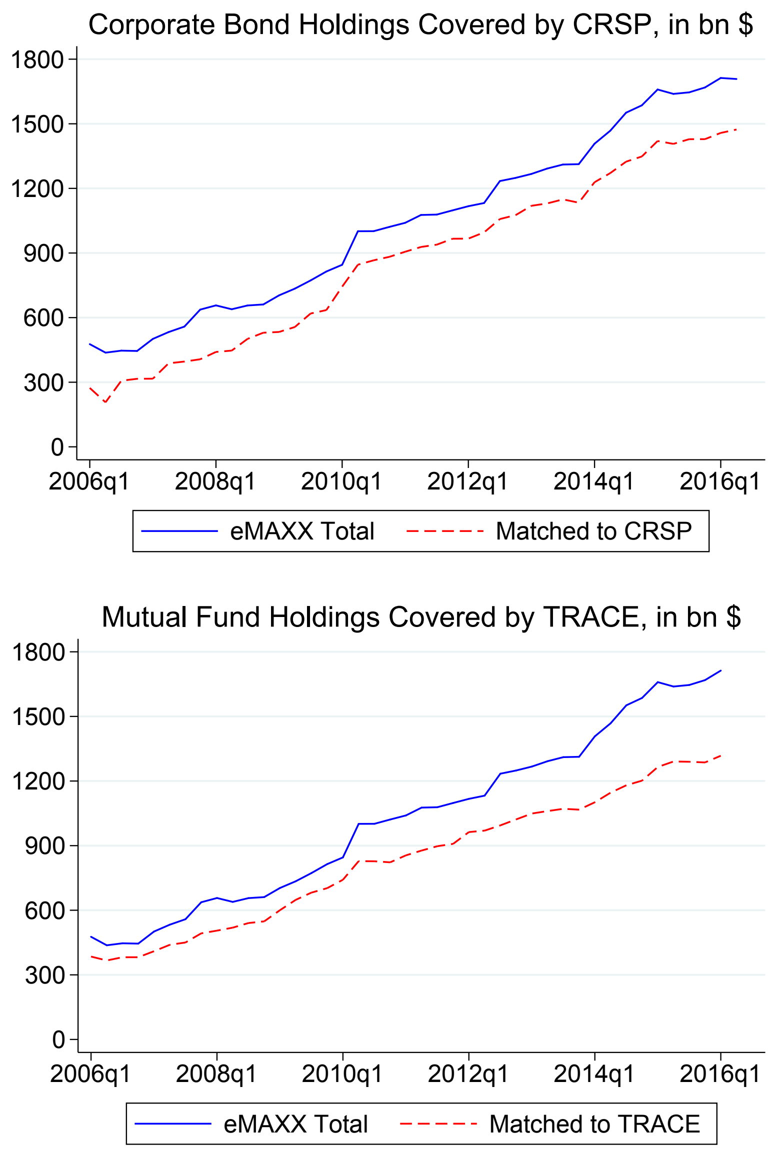

Figure 2: **Fragility Measure**

This figure shows the time trend of three bond-level fragility measures defined in Appendix A, calculated as value-weighted mean for a given quarter.

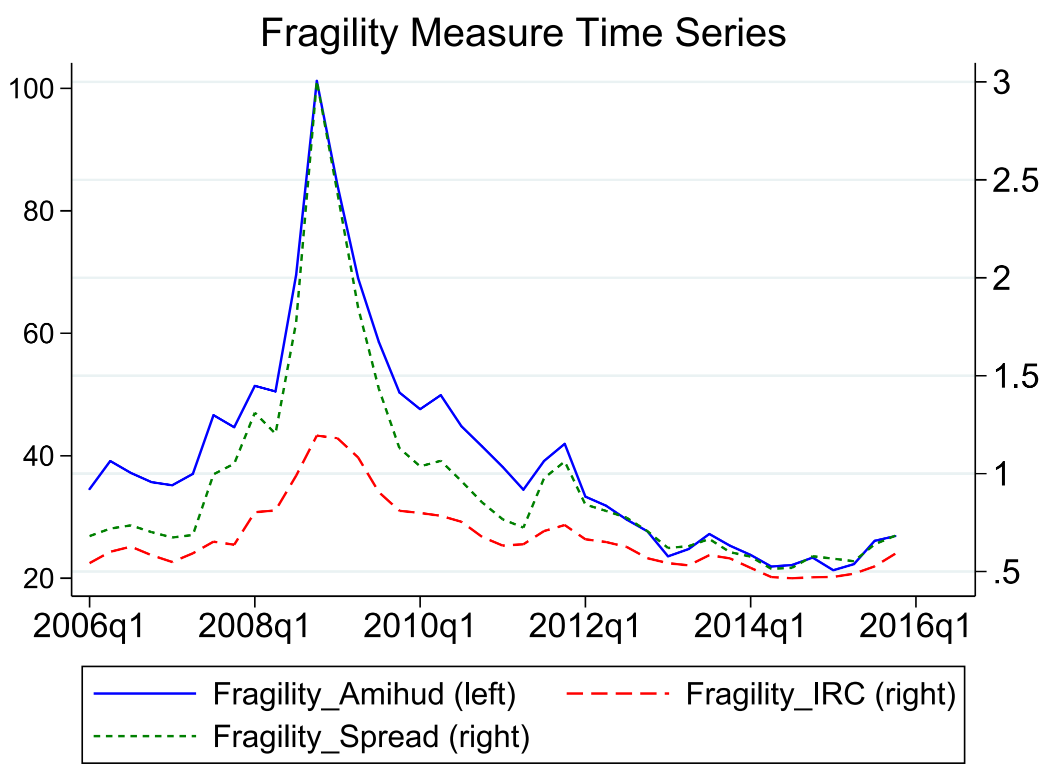

Table 1: **Summary Statistics**

This table provides summary statistics for variables defined in Appendix A.

Panel A: Distribution of Main Variables

Variable	N	Mean	S.D.	P25	Median	P75
Fragility_Amihud	82864	40.05	22.11	25.22	34.28	48.06
Fragility_IRC	82864	0.68	0.24	0.53	0.64	0.80
Fragility_Spread	82864	0.96	0.56	0.62	0.79	1.10
Amihud (% per $mn)	82864	62.69	94.37	9.78	32.49	75.54
IRC (%)	81681	0.81	0.73	0.28	0.59	1.13
Spread (%)	80115	1.31	1.25	0.47	0.91	1.74
Turnover (%)	82864	14.91	16.60	3.96	9.77	19.81
Return	82864	0.09	0.35	0.00	0.06	0.16
Return_SD	81467	0.12	0.12	0.05	0.09	0.15
Rating	82864	9.13	3.69	6.33	8.67	11.50
Size (in thousands)	82864	518475	504115	250000	375000	600000
Maturity (in months)	82864	104	95	41	72	115
Coupon	82864	6.18	1.82	5.15	6.22	7.25
Stock_Vol	82864	0.02	0.02	0.01	0.02	0.02
Skewness_Amihud	78681	0.56	1.85	-0.21	0.49	1.25
Skewness_IRC	78681	0.29	1.86	-0.46	0.28	1.03
Skewness_Spread	78680	0.47	1.89	-0.32	0.42	1.20
MF_Ownership	82864	0.16	0.15	0.04	0.10	0.23
MF_Cash (%)	81102	3.07	2.74	1.22	2.31	4.06
Sell_Pressure	81882	-0.0003	0.0047	-0.0001	0	0

Panel B: Correlations

	F_Amihud	F_IRC	F_Spread	Amihud	IRC	Spread	MF_Own	MF_Cash
Fragility_Amihud	1.00							
Fragility_IRC	0.84	1.00						
Fragility_Spread	0.90	0.89	1.00					
Amihud	0.36	0.34	0.32	1.00				
IRC	0.38	0.48	0.37	0.36	1.00			
Spread	0.53	0.57	0.56	0.60	0.61	1.00		
MF_Ownership	-0.23	-0.05	-0.11	-0.14	-0.10	-0.14	1.00	
MF_Cash	0.12	0.15	0.17	0.04	0.04	0.08	0.16	1.00

Table 2: **Fragility Measure and Bond Volatility: Baseline**

This table reports regression results. The dependent variable is the standard deviation of corporate bond returns measured in quarter $t+1$. The independent variables are measured as of quarter t and defined in Appendix A. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: Standard deviation of bond returns in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.0007***			0.0003***		
	(7.07)			(3.05)		
Fragility_IRC		0.0556***			0.0276**	
		(6.78)			(2.10)	
Fragility_Spread			0.0264***			0.0190**
			(5.35)			(2.35)
Amihud	0.0002***			0.0001***		
	(12.47)			(8.91)		
IRC		0.0281***			0.0099***	
		(13.26)			(6.70)	
Spread			0.0282***			0.0169***
			(19.25)			(12.97)
Turnover	-0.0001	-0.0003***	-0.0000	-0.0003***	-0.0003***	-0.0002**
	(-1.45)	(-3.03)	(-0.17)	(-2.71)	(-3.31)	(-2.14)
Rating	0.0038***	0.0024**	0.0029***	0.0110***	0.0106***	0.0096***
	(3.56)	(2.34)	(2.79)	(4.38)	(4.32)	(4.13)
log(Size)	-0.0203***	-0.0214***	-0.0163***	-0.0212***	-0.0258***	-0.0209***
	(-11.68)	(-12.35)	(-8.36)	(-4.00)	(-4.78)	(-3.96)
Return	-0.0421***	-0.0335***	-0.0404***	-0.0412***	-0.0353***	-0.0398***
	(-2.73)	(-2.72)	(-2.96)	(-3.47)	(-3.68)	(-3.77)
Coupon	-0.0012	0.0001	-0.0004			
	(-1.24)	(0.11)	(-0.44)			
log(Maturity)	0.0460***	0.0387***	0.0368***	0.0283***	0.0278***	0.0235***
	(16.55)	(13.88)	(13.17)	(5.15)	(5.01)	(4.52)
Stock_Vol	3.0242***	3.0124***	2.4898***	2.7302***	2.7760***	2.4869***
	(10.08)	(9.65)	(8.81)	(10.82)	(10.37)	(9.62)
Constant	0.0662***	0.0964***	0.0417*	0.1079*	0.1659***	0.1192**
	(2.97)	(4.57)	(1.84)	(1.90)	(2.90)	(2.18)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.564	0.563	0.594	0.665	0.660	0.672
N of obs	82864	86848	82019	82428	86430	81575

Table 3: **Fragility Measure and Bond Illiquidity: Baseline**

This table reports regression results. The dependent variables are corporate bonds' illiquidity measures in quarter $t+1$, in the sequence of Amihud, IRC, and Spread. The independent variables are measured as of quarter t and defined in Appendix A. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: Bond illiquidity measures in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.6497***			0.5484***		
	(10.13)			(9.37)		
Fragility_IRC		0.3891***			0.3941***	
		(13.84)			(8.61)	
Fragility_Spread			0.4955***			0.7697***
			(9.40)			(10.25)
Amihud	0.4362***					
	(24.70)					
IRC		0.4073***				
		(33.80)				
Spread			0.5706***			
			(22.39)			
Turnover	-0.0114	0.0004**	0.0006	-0.1388***	0.0005**	-0.0015***
	(-0.38)	(2.15)	(1.59)	(-4.57)	(2.04)	(-2.91)
Rating	-0.8008***	0.0018	-0.0010	3.0699***	0.0272***	0.0656***
	(-3.42)	(1.09)	(-0.23)	(3.67)	(4.29)	(3.82)
log(Size)	-8.5198***	-0.0449***	-0.0709***	-20.0605***	-0.0716***	-0.2111***
	(-9.60)	(-9.53)	(-6.10)	(-6.09)	(-3.67)	(-4.98)
Return	-6.0050**	-0.0348**	-0.1357***	-2.4098	-0.0177	-0.0682*
	(-2.41)	(-2.47)	(-4.42)	(-1.07)	(-1.60)	(-1.83)
Coupon	2.2838***	-0.0067**	-0.0007			
	(6.49)	(-2.66)	(-0.14)			
log(Maturity)	10.3589***	0.1964***	0.1693***	14.8969***	0.1625***	0.3450***
	(10.91)	(17.37)	(11.27)	(4.87)	(5.16)	(9.93)
Stock_Vol	415.0268***	3.8355***	9.4268***	691.5248***	3.5299***	17.8643***
	(5.91)	(6.08)	(5.26)	(7.22)	(3.71)	(10.08)
Constant	60.1182***	-0.1135	0.0854	193.3446***	0.4377	0.8341*
	(4.84)	(-1.61)	(0.53)	(4.83)	(1.50)	(1.71)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.328	0.415	0.585	0.444	0.486	0.644
N of obs	81496	91167	80466	81031	90762	79965

Table 4: **Fragility Measure, Selling Pressure and Return Reversal**

This table reports regression results of bond abnormal returns in quarter t and $t+1$ on bond characteristics measured in quarter t. $m+1$ stands for the first month in quarter $t+1$; $m+2$ the second; $m+3$ the third. All returns are annualized abnormal returns (relative to the mean return of bonds with similar ratings and time-to-maturity during the same period). Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Dependant variables: Bond abnormal returns in current quarter and 1-3 months ahead											
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	t	$m+1$	$m+2$	$m+3$	t	$m+1$	$m+2$	$m+3$	t	$m+1$	$m+2$	$m+3$
Pressure×Fragility_Amihud	-0.0259	0.0605**	0.0722*	0.0040								
	(-1.30)	(2.64)	(1.83)	(0.19)								
Pressure×Fragility_IRC					-2.8950*	4.8997*	5.3198	1.5259				
					(-1.74)	(1.69)	(1.38)	(0.66)				
Pressure×Fragility_Spread									-1.4568**	2.4499***	2.6120*	0.2634
									(-2.29)	(2.89)	(1.78)	(0.23)
Pressure	0.2118	-1.2137**	-1.1051	0.5467	1.2784	-2.4820	-2.5368	-0.3531	0.5493	-1.7664**	-1.4340	0.2045
	(0.37)	(-2.03)	(-1.15)	(0.82)	(1.31)	(-1.52)	(-1.16)	(-0.24)	(1.13)	(-2.57)	(-1.27)	(0.23)
Fragility_Amihud	0.0000	0.0001	0.0000	0.0001								
	(0.19)	(0.52)	(0.13)	(0.41)								
Fragility_IRC					0.0333*	0.0446**	0.0521**	0.0054				
					(1.90)	(2.17)	(2.47)	(0.20)				
Fragility_Spread									0.0277*	0.0120	0.0132	0.0153
									(1.82)	(0.84)	(0.86)	(0.49)
Amihud	-0.0001	0.0000	-0.0000	0.0000								
	(-1.40)	(0.75)	(-0.07)	(0.22)								
IRC					-0.0059	0.0073	0.0094	0.0135				
					(-1.07)	(1.19)	(1.38)	(1.52)				
Spread										0.0219**	0.0148	0.0130
									(-0.70)	(2.33)	(1.35)	(1.38)
Constant	-0.0011	-0.0193*	0.0041	-0.0114	-0.0226*	-0.0498***	-0.0383**	-0.0198	-0.0235	-0.0504***	-0.0265	-0.0362
	(-0.15)	(-1.92)	(0.54)	(-0.83)	(-1.81)	(-3.33)	(-2.42)	(-1.01)	(-1.59)	(-2.85)	(-1.53)	(-1.20)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.004	0.004	0.003	0.006	0.003	0.004	0.004	0.006	0.004	0.007	0.005	0.007
N of obs	141800	143662	139538	137648	130053	131918	128215	127169	140294	142329	138082	136231

Table 5: **Interacting Fragility Measure with VIX**

This table reports regression results. Panel A and B have the same model specifications as in Table 2 and Table 3, respectively, with the inclusion of the interaction terms with VIX. Standard errors are clustered at the bond and quarter levels, with corresponding *t*-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × VIX	0.00001*			0.000004		
	(1.78)			(1.25)		
Fragility_IRC × VIX		0.0052***			0.0046***	
		(9.71)			(7.90)	
Fragility_Spread × VIX			0.0012***			0.0010***
			(4.47)			(3.49)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × VIX	-0.0027			0.0068***		
	(-1.21)			(3.10)		
Fragility_IRC × VIX		0.0107***			0.0138***	
		(3.17)			(4.59)	
Fragility_Spread × VIX			0.0037			0.0121***
			(1.12)			(4.82)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Table 6: **Interacting Fragility Measure with Aggregate Fund Flows**

This table reports regression results. Panel A and B have the same model specifications as in Table 2 and Table 3, respectively, with the inclusion of the interaction terms with aggregate bond mutual fund flows. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × Agg_Flow	-0.0028			-0.0021		
	(-1.22)			(-1.21)		
Fragility_IRC × Agg_Flow		-1.2657**			-1.3427***	
		(-2.41)			(-2.83)	
Fragility_Spread × Agg_Flow			-0.3817**			-0.3430**
			(-2.30)			(-2.28)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × Agg_Flow	-4.0204			-2.1962		
	(-0.98)			(-0.57)		
Fragility_IRC × Agg_Flow		0.8164			1.0825	
		(0.71)			(0.96)	
Fragility_Spread × Agg_Flow			-6.0729***			-5.1661***
			(-5.09)			(-3.20)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Table 7: **Fragility Measure and Return Reversal**

This table reports regression results of monthly bond returns in quarter $t+1$ on bond characteristics measured in quarter t. $m+1$ stands for the first month in quarter $t+1$; $m+2$ the second; $m+3$ the third. All returns are annualized abnormal returns (relative to the mean return of bonds with similar ratings and time-to-maturity during the same period). Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Dependant variables: Bond monthly abnormal returns, 1-3 months ahead								
	(1) $m+1$	(2) $m+2$	(3) $m+3$	(4) $m+1$	(5) $m+2$	(6) $m+3$	(7) $m+1$	(8) $m+2$	(9) $m+3$
AbReturn × Fragility_Amihud	-0.0050***	-0.0029**	-0.0012						
	(-3.90)	(-2.33)	(-0.85)						
AbReturn × Amihud	-0.0005***	-0.0003*	-0.0005***						
	(-2.84)	(-1.72)	(-3.56)						
Fragility_Amihud	-0.0002	-0.0002	-0.0000						
	(-0.54)	(-0.65)	(-0.12)						
Amihud	0.0000	0.0000	0.0000						
	(0.61)	(0.25)	(0.45)						
AbReturn × Fragility_IRC				-0.3396*	-0.1862	-0.0686			
				(-1.86)	(-1.01)	(-0.42)			
AbReturn × IRC				-0.0352	-0.0128	-0.0232			
				(-1.26)	(-0.59)	(-0.83)			
Fragility_IRC				0.0469*	0.0593**	-0.0050			
				(1.83)	(2.57)	(-0.19)			
IRC				0.0083	0.0115*	0.0154*			
				(1.27)	(1.70)	(1.80)			
AbReturn × Fragility_Spread							-0.1815***	-0.1281**	-0.0468
							(-3.31)	(-2.41)	(-0.86)
AbReturn × Spread							0.0147	0.0150	0.0071
							(1.04)	(1.41)	(0.67)
Fragility_Spread							0.0180	0.0182	0.0060
							(0.84)	(1.07)	(0.20)
Spread							0.0214**	0.0159	0.0154*
							(2.43)	(1.54)	(1.70)
AbReturn	0.2497**	0.3643***	0.2518**	0.2833*	0.3682**	0.2592	0.1393	0.3197***	0.1696
	(2.67)	(4.69)	(2.06)	(1.80)	(2.36)	(1.39)	(1.40)	(3.40)	(1.16)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.020	0.017	0.013	0.012	0.014	0.013	0.018	0.017	0.011
N of obs	136121	132617	130894	125530	122574	121529	134565	131050	129359

Table 8: **Predicting Bond Volatility and Liquidity with Skewness Fragility**

This table reports regression results. Panel A and B have the same model specifications as in Table 2 and Table 3, respectively, with the inclusion of skewness fragility measures. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t+1$

	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.0008***			0.0003**		
	(6.36)			(2.20)		
Fragility_IRC		0.0723***			0.0271	
		(6.43)			(1.67)	
Fragility_Spread			0.0329***			0.0169
			(4.70)			(1.59)
Skewness_Amihud	0.0010***			-0.0000		
	(3.04)			(-0.08)		
Skewness_IRC		0.0014***			0.0002	
		(4.18)			(0.63)	
Skewness_Spread			0.0009***			-0.0001
			(3.43)			(-0.40)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t+1$

	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.7251***			0.6290***		
	(10.64)			(9.06)		
Fragility_IRC		0.5198***			0.5262***	
		(12.81)			(9.17)	
Fragility_Spread			0.6199***			0.8826***
			(11.63)			(10.08)
Skewness_Amihud	1.1529***			0.4585		
	(3.49)			(1.39)		
Skewness_IRC		0.0136***			0.0105***	
		(6.81)			(4.48)	
Skewness_Spread			0.0147***			0.0155***
			(5.24)			(5.53)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Table 9: **Controlling for Mutual Fund Ownership**

This table reports regression results. Panel A and B have the same model specifications as in Table 2 and Table 3, respectively, with the inclusion of mutual fund ownership. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.0006***			0.0003***		
	(7.09)			(3.18)		
Fragility_IRC		0.0587***			0.0315**	
		(7.39)			(2.42)	
Fragility_Spread			0.0268***			0.0200**
			(5.51)			(2.50)
MF_Ownership	-0.1170***	-0.1146***	-0.0925***	-0.1185***	-0.1188***	-0.1087***
	(-10.18)	(-10.17)	(-9.46)	(-6.05)	(-5.95)	(-6.03)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.6339***			0.5494***		
	(10.16)			(9.42)		
Fragility_IRC		0.3990***			0.3972***	
		(14.16)			(8.62)	
Fragility_Spread			0.4987***			0.7739***
			(9.49)			(10.41)
MF_Ownership	-36.5025***	-0.3860***	-0.6543***	-33.4494***	-0.1089	-0.8022***
	(-7.73)	(-11.26)	(-8.82)	(-4.19)	(-1.43)	(-5.25)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Table 10: **Controlling for Cash Holdings**

This table reports regression results. Panel A and B have the same model specifications as in Table 2 and Table 3, respectively, with the inclusion of bond-level cash holdings. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.0007***			0.0003***		
	(6.66)			(2.98)		
Fragility_IRC		0.0568***			0.0307**	
		(6.65)			(2.08)	
Fragility_Spread			0.0272***			0.0215**
			(4.97)			(2.17)
Cash_Holding	-0.0005*	-0.0006**	-0.0005*	0.0002	0.0001	0.0003
	(-1.84)	(-2.36)	(-1.70)	(0.61)	(0.43)	(0.77)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.6906***			0.5888***		
	(10.02)			(9.68)		
Fragility_IRC		0.4048***			0.4263***	
		(14.27)			(8.13)	
Fragility_Spread			0.5227***			0.8229***
			(9.93)			(10.71)
Cash_Holding	0.2523	-0.0019	-0.0006	-0.4122**	-0.0030*	-0.0062**
	(1.59)	(-1.24)	(-0.30)	(-2.27)	(-1.90)	(-2.17)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes

Table A1: **Subsamples by Mutual Fund Ownership**

This table reports regression results. A bond in quarter t is defined to have high (low) mutual-fund ownership if its mutual fund ownership is above (below) the median level in quarter t. Panel A and B have the same model specifications as in Columns (1)-(3) of Table 2 and Table 3, respectively. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t+1$

	High MF Ownership			Low MF Ownership		
	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.0009***			0.0003***		
	(6.90)			(2.76)		
Fragility_IRC		0.0841***			0.0317***	
		(6.77)			(4.09)	
Fragility_Spread			0.0318***			0.0208***
			(4.37)			(3.51)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t+1$

	High MF Ownership			Low MF Ownership		
	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.7084***			0.3962***		
	(7.97)			(6.16)		
Fragility_IRC		0.5435***			0.2311***	
		(11.46)			(7.24)	
Fragility_Spread			0.5574***			0.3405***
			(7.91)			(6.99)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes

Table A2: **Subsamples by Bond Ratings**

This table reports regression results for investment-grade and high-yield bonds separately. Panel A and B have the same model specifications as in Columns (1)-(3) of Table 2 and Table 3, respectively. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t + 1$

	Investment-Grade			High-Yield		
	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.0003***			0.0009***		
	(3.39)			(6.94)		
Fragility_IRC		0.0294***			0.1062***	
		(4.73)			(7.41)	
Fragility_Spread			0.0211***			0.0395***
			(2.99)			(5.70)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t + 1$

	Investment-Grade			High-Yield		
	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.5013***			0.6922***		
	(6.52)			(6.51)		
Fragility_IRC		0.2517***			0.5273***	
		(8.00)			(11.63)	
Fragility_Spread			0.3560***			0.4682***
			(6.92)			(8.74)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes

Table A3: **Subsamples Defined by Financial Crisis**

This table reports regression results for different time periods. Panel A and B have the same model specifications as in Columns (1)-(3) of Table 2 and Table 3, respectively. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter $t+1$

	Pre-Crisis (before 07'Q3)			During Crisis			Post-Crisis (after 09'Q2)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.0005***			0.0007***			0.0007***		
	(4.79)			(8.46)			(5.63)		
Fragility_IRC		0.0344***			0.0722***			0.0610***	
		(4.94)			(4.62)			(5.42)	
Fragility_Spread			0.0174*			0.0460***			0.0264***
			(2.18)			(7.63)			(4.90)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter $t+1$

	Pre-Crisis (before 07'Q3)			During Crisis			Post-Crisis (after 09'Q2)		
	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.4563***			0.5102***			0.7636***		
	(6.51)			(4.82)			(7.95)		
Fragility_IRC		0.3245***			0.3174***			0.3994***	
		(5.82)			(5.09)			(13.31)	
Fragility_Spread			0.3511***			0.5948***			0.3729***
			(6.14)			(6.70)			(9.86)
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Table A4: **Post-Crisis Subsamples Defined by Volcker Rule**

This table reports regression results for different time periods. Pre-Volcker period is defined as 2009Q3-2014Q2, and post-Volcker period is defined as 2014Q3-2016Q1. Panel A and B have the same model specifications as in Columns (1)-(3) of Table 2 and Table 3, respectively. Standard errors are clustered at the bond and quarter levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Panel A: Dependent variable: Standard deviation of bond returns in quarter t+1

	Pre-Volcker			Post-Volcker		
	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.0006***			0.0012***		
	(5.34)			(5.69)		
Fragility_IRC		0.0467***			0.1079***	
		(7.25)			(3.93)	
Fragility_Spread			0.0213***			0.0398**
			(4.64)			(2.64)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes

Panel B: Dependent variable: Bond illiquidity measures in quarter t+1

	Pre-Volcker			Post-Volcker		
	(1)	(2)	(3)	(1)	(2)	(3)
Fragility_Amihud	0.7106***			1.0289***		
	(7.08)			(14.50)		
Fragility_IRC		0.3786***			0.4668***	
		(13.01)			(6.35)	
Fragility_Spread			0.3517***			0.4541***
			(8.90)			(4.62)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes