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

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First Draft: December 2019

This Version: September 2020

Abstract

Open-end mutual funds have grown to become a key player in the corporate bond market. They invest in illiquid bonds but provide liquid claims to shareholders. Does such liquidity transformation introduce fragility to the corporate bond market? To address this question, we create a novel measure of latent fragility in individual corporate bonds based on the asset illiquidity of their mutual fund holders. We find that corporate bonds with higher fragility tend to experience higher future return volatility, after controlling for a rich set of bond characteristics. Moreover, these bonds tend to have more outflows-induced mutual fund selling in the subsequent period. Using the Covid-19 pandemic as a natural experiment, we find that corporate bonds with higher latent fragility at the end of 2019 experienced more negative returns and larger subsequent reversals around March 2020.

Keywords: Corporate bond mutual fund, Liquidity transformation, Fragility, Volatility

JEL Codes: G10, G12, G20, G23

*The views expressed herein are those of the authors and do not necessarily reflect those of the Federal Reserve Board or its staff. For helpful comments, We thank Xing (Alex) Zhou, Qifei Zhu, and virtual seminar participants at Board of Governors of the Federal Reserve System, the SEC, and Nanyang Technological University. Hao Jiang is at Michigan State University, email: jiangh@broad.msu.edu; Yi Li is at Board of Governors of the Federal Reserve System, email: yi.li@frb.gov; Zheng Sun is at University of California, Irvine, email: zhengs@uci.edu; and Ashley Wang is at Board of Governors of the Federal Reserve System, email: ashley.wang@frb.gov. Frank Ye provided excellent research assistance.

1 Introduction

Since the 2008–2009 global financial crisis, open-end bond funds have experienced substantial growth and become a significant player in the credit market. According to the 2020 Investment Company Institute Fact Book, they received net cash inflows of $2.2 trillion during the past decade from 2010 to 2019, holding approximately 11% of the U.S. fixed-income market. In the corporate bond market, the influence of bond funds is even greater. The Thomson Reuters eMAXX database shows that mutual funds held $1.89 trillion of corporate bonds in 2019, which accounted for approximately 20% of the $9.60 trillion corporate bonds outstanding.[1] For the high-yield corporate bond market, the 2020 International Monetary Fund Global Financial Stability Report estimated that more than 40% of the high-yield bonds were owned by mutual funds.

The distinctive feature of open-end corporate bond funds is the high liquidity they provide to their shareholders—the daily redeemability of mutual fund shares—despite that the funds' assets are invested in relatively illiquid corporate bonds. A growing literature studies how the liquidity transformation of mutual funds might generate a first-mover advantage among their investors in situations of adverse shocks, which leads to amplified redemption responses (See, e.g., Chen, Goldstein, and Jiang (2010), Goldstein, Jiang, and Ng (2017), and Zeng (2017)). The literature broadly concludes that the asset illiquidity of mutual funds renders them vulnerable to investor runs, which may create fragility in the mutual fund sector.[2]

In this paper, we study whether the asset illiquidity of mutual funds introduces fragility to the corporate bond market. To this end, we create a novel bond-level measure of latent fragility based on the asset illiquidity of a bond's mutual fund holders. It integrates 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 this measure, if a bond is 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, investors in an illiquid bond fund have greater incentives to redeem their

[1]The Securities Industry and Financial Markets Association (SIFMA) reported the dollar value of the U.S. corporate bonds outstanding.

[2]This conclusion resonates with the message from the earlier literature on how runs might originate from the liquidity transformation provided by banks and money market funds (see, e.g., Diamond and Dybvig (1983), Gorton and Pennacchi (1990), Gorton, Metrick, Shleifer, and Tarullo (2010), Kacperczyk and Schnabl (2013), and Schmidt, Timmermann, and Wermers (2016)). Ma, Xiao, and Zeng (2019) provide a framework to study the role of bank debt versus mutual fund equity in liquidity transformation.

shares ahead of others; accordingly, when a bond is mainly held by illiquid funds, negative shocks can trigger larger outflows from funds holding that bond (Goldstein, Jiang, and Ng (2017)). Since large outflows would ultimately lead mutual funds to sell their bond holdings for non-fundamental reasons, the bond could have larger swings in prices, thus entailing higher fragility.

To estimate latent fragility, we use three commonly used illiquidity proxies to measure the illiquidity of a mutual fund's corporate bond portfolio: the Amihud measure, imputed round-trip cost (IRC), and effective bid-ask spread. We apply our algorithm to a sample of 3,288 fixed-income funds with significant corporate holdings during 2006 and 2019. We then calculate the bond-level latent fragility measures as the average illiquidity levels of the bond's investing funds. These three fragility measures generate consistent results in our empirical tests.

In our baseline analyses, we use latent fragility to predict a bond's return volatility in the subsequent quarter, and find that corporate bonds with higher fragility tend to have higher future return volatility. This relation is not only statistically significant but economically large. For instance, one standard deviation increase in bond fragility based on the Amihud measure is associated with an increase of 1.15% in the annualized bond return volatility over the next quarter, which is approximately 16% of the median level of bond volatility. It is robust to controlling for the effects of a variety of bond characteristics such as credit rating, maturity, illiquidity and mutual fund ownership. It remains strong even when we control for the current bond return volatility or include bond fixed effects that absorb the cross-sectional variation.

What drives the predictive power of latent fragility for bond return volatility? The central idea behind the fragility measure is that the strategic complementarities among investors of illiquid mutual funds incentivize them to redeem shares at the first sign of trouble; to accommodate investor redemption, the fund managers may be forced to liquidate some of their bond holdings, which would destabilize bond prices. Hence, the key source of the predictive power should be the link between fragility and outflows-induced selling by the mutual funds holding the bond. To flesh out this link, we first run predictive regressions of outflows-induced selling (Coval and Stafford (2007)) on fragility. The results indicate that a bond with higher fragility indeed has more outflows-induced selling in the next quarter. We then show that such outflows-induced selling is accompanied by price declines in the same quarter and gradual price reversals in the subsequent quarters. Combined, these results provide evidence that fragility affects bond return volatility mainly through the channel of mutual fund flow-induced selling pressure.

The recent corporate bond market turmoil brought about by the Covid-19 pandemic allows us to perform a close-up analysis on how fragility manifests itself in bond price movements over the crisis. At the height of the crisis in March 2020, the corporate bond market was hit hard and bond mutual funds saw substantial outflows. To illustrate how fragility induced by fund asset illiquidity affects the price resilience of corporate bonds, we group corporate bonds into three portfolios based on their fragility scores measured at the end of 2019. Panel A of Figure 1 presents the weekly returns in early 2020 on the top and bottom fragility tercile portfolios. It shows that the performance of high and low fragility bonds clustered closely in January and February 2020; after the pandemic hit, however, returns on the high-fragility tercile dived twice as deep as those on the low-fragility tercile, reaching -10% right before March 23 when the Federal Reserve announced the Secondary Market Corporate Credit Facility (SMCCF); quickly following the SMCCF announcement, corporate bond prices rebounded, more so for the high-fragility tercile portfolio. Panel B shows a consistent pattern of price movements based on yield spreads of these two portfolios. Formal regression tests provide further evidence that our latent fragility measures, based on data prior to the on-set of the crisis, strongly affect bond price dynamics during the crisis at the individual bond level.

In light of the strong predictive power of fragility for bond price movements during the Covid-19 crisis, it is natural to investigate whether our fragility measures in general have a larger impact on bond price volatility at times of stress over our full sample period. Using a set of aggregate measures based on both financial market stress and real economic activities, we find that fragility has a stronger association with future bond return volatility over periods with high VIX, during episodes of flight-to-safety, and through economic downturns. Such evidence provides further support to the notion that the asset illiquidity of mutual funds introduces fragility into the corporate bond market, rendering it vulnerable to adverse shocks.

We proceed to perform a battery of tests to deepen our understanding of how mutual fund asset illiquidity might shape the behavior of corporate bond prices. First, given our findings that latent fragility strongly predicts excessive movements of bond prices, especially during crisis, it is possible that some investors may require higher returns out of bonds with higher fragility. Indeed, we find that fragility is positively related to future bond returns and contemporaneous bond yield spreads, after controlling for multiple characteristics.

Second, we examine whether liquidity commonality could serve as an alternative interpretation of our findings. The literature shows a substantial co-movement in corporate bond illiquidity.(e.g. Bao, Pan, and Wang (2011)). This implies that for a given bond, the aggregate liquidity of other bonds held in its investing funds' portfolios could contain incremental information, beyond the bond's own illiquidity level, about this bond's future liquidity and thus price volatility. To assess the validity of this conjecture, we first conduct rolling-window regressions to estimate each bond's exposure to the market liquidity, i.e., liquidity beta. The higher the liquidity beta of a bond, the more likely the bond's liquidity co-moves with other bonds' liquidity. If liquidity commonality drove our findings, we would expect controlling for liquidity beta to weaken volatility predicting power of our fragility measures. Yet, our results show that fragility measures continue to significantly predict bond volatility in the presence of liquidity beta, both in the Covid-19 setting and over the full sample. In sum, our findings do not support liquidity commonality as the alternative channel underlying our results.

Third, we evaluate whether information asymmetry may be another driving force of our main results. It is possible that some mutual funds have better information-collecting skills and self-select into holding bonds with higher degrees of information asymmetry, which could lead to higher portfolio illiquidity and higher bond volatility at the same time. The literature on information asymmetry generally suggests that private information tends to be incorporated into priced gradually (Llorente, Michaely, Saar, and Wang (2002)). Hence, if bond fragility reflects information asymmetry, we may expect stronger return continuation for bonds with higher fragility. In contrast, if bond fragility reflects the selling 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. To distinguish between these two hypotheses, we examine how fragility affects the serial dependence in bond returns. Our results show that fragility tends to increase negative autocorrelations in corporate bond returns, which supports the theory of selling pressure, rather than that of information asymmetry.

Finally, we find that liquid asset holdings of mutual funds such as cash and government bonds help to mitigate the impact of fragility on bond volatility, but higher allocations to corporate bonds by mutual funds tend to intensify such an impact. These results suggest that the fragility effect of mutual funds' asset illiquidity could be alleviated or amplified by other aspects of fund liquidity conditions.

Our paper connects the literature on the liquidity transformation of corporate bond mutual funds to the literature on the behavior of the corporate bond market. As discussed previously, the former literature emphasizes the importance of mutual fund asset illiquidity for the fragility in the corporate bond mutual fund sector (See, e.g., Chen, Goldstein, and Jiang (2010), Goldstein, Jiang, and Ng (2017), and Zeng (2017)). The latter highlights the illiquidity and excess volatility of corporate bonds and their importance for bond pricing, beyond fundamental factors such as the credit risk of corporate bonds (See, e.g., Chen, Lesmond, and Wei (2007), Bao, Pan, and Wang (2011) and Bao and Pan (2013)). Our empirical results show that the concentrated illiquidity of corporate bonds through mutual fund portfolios can generate fragility, leading to excess movements of corporate bond prices.

Because of its central role in providing credit and investment choices to the economy, the corporate bond market has been under scrutiny during episodes of market distress. For instance, Friewald, Jankowitsch, and Subrahmanyam (2012) and Dick-Nielsen, Feldhütter, and Lando (2012) study the behavior of corporate bonds during the 2008–2009 financial crisis. The recent Covid-19 crisis, in which the corporate bond market was hit hard, has engendered a strong interest in understanding the behavior of corporate bonds during the Covid-19 period (See, e.g., Haddad, Moreira, and Muir (2020), Kargar, Lester, Lindsay, Liu, Weill, and Zuniga (2020), O'Hara and Zhou (2020), and Falato, Goldstein, and Hortacsu (2020)). Our paper provides an ex ante measure of fragility observed in 2019 that strongly predicts the price dislocations for individual corporate bonds in the Covid-19 crisis.

Our paper also helps enrich the understanding on drivers of corporate bond mutual fund fire sales. Empirical studies on mutual fund fire sales in the corporate bond market have focused largely on how bond prices behave when fire sales occur, conditioning on investor redemptions (See, e.g., Falato, Hortacsu, Li, and Shin (2019), Choi, Hoseinzade, Shin, and Tehranian (2020), and Jiang, Li, and Wang (2020)). However, relatively little is known about what leads to mutual fund fire sales in the first place. Our paper shows that asset illiquidity of mutual fund holders plays a vital role in leading up to redemption-induced sales of corporate bonds, which provides a micro foundation for the observed market outcomes.

Finally, our paper extends a small but growing literature on how the composition of institutional investors impacts the corporate bond market. For instance, Mahanti, Nashikkar, Subrahmanyam, Chacko, and Mallik (2008) show that corporate bonds held by mutual funds with high turnover tend to have lower transaction costs; Anand, Jotikasthira, and Venkataraman (2020) emphasize heterogeneous trading styles of corporate bond funds; Chen, Huang, Sun, Yao, and Yu (2020) find that corporate bonds with a higher fraction owned by insurance companies that exhibit weaker preference for liquidity have lower liquidity premiums. Our paper differs by focusing on the impact of mutual fund asset illiquidity on corporate bond price volatility through mutual fund selling pressure. In an era with substantial expansion of mutual fund ownership in corporate bond market, this line of research may be particularly fruitful.

The rest of the paper is organized as follows. Section 2 offers a description for data set, summary statistics, and detailed explanations on the construction of bond-level fragility measures based on mutual fund asset illiquidity. Section 3 shows the baseline results on the predictive power of fragility for bond volatility and investigates the underlying mechanism. Section 4 starts with a thorough anatomy of how fragility predicts bond prices over the Covid-19 crisis period, and expands to examine how fragility affects bond volatility at boarder times of stress. Section 5 provides further discussions on the pricing implications of fragility measures, alternative mechanisms, and how other aspects of mutual fund asset liquidity affect the impact of fragility. We conclude in Section 6.

2 Data and Fragility Measures

2.1 Data and Sample Construction

Our study combines data from several sources, spanning a sample period from January 2006 to March 2020.[3] 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, Han, Li, and Li (2019), among others. This data set is survivorship-bias free, and contains security-level fixed-income holdings at quarter-ends from 2006:Q1 to 2019:Q4 for institutional investors including mutual funds. To ensure that our sample funds maintain significant positions in corporate bonds, we exclude funds if (i) their maximum holdings of corporate bonds across all quarters are less than $1 million; or (ii) their corporate bond holdings never exceed 10% of the fixed-income holdings

[3]For the analyses on the Covid-19 crisis, our data sample extends to April 2020.

across all quarters. These lead to 4192 eMAXX mutual funds.[4] Figure 2 shows the share of U.S. corporate bonds held by these 4192 mutual funds over the sample period of 2006–2019 (as of year-ends). In particular, mutual funds have held increasingly more corporate bonds over time, with ownership rising from 8% in 2006 to 20% in 2019.[5]

We then match our eMAXX sample funds to the mutual funds covered in the CRSP survivor-bias free mutual fund database based on fund names, to obtain fund characteristics such as asset under management (AUM) and cash holding composition.[6] The matching process yields a sample of 3288 funds, whose corporate bond holdings make up over 90% of total corporate holdings by all eMAXX funds.

Next, we use the enhanced TRACE database to gather information about corporate bond transactions and prices. Applying standard filters for the TRACE data, we remove canceled and corrected trades, and exclude commission trades and inter-dealer trades. We construct 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[7]; 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.[8] The construction methodologies are detailed in Appendix A. Note that the higher these three measures are, the more illiquid the bond is. All three illiquidity measures are winsorized at 1% and 99% levels.

We supplement the bond 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.

Finally, we merge corporate bond information obtained from TRACE and FISD to the holding

[4]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.

[5]It is worth noting that although mutual funds are not the largest institutional holders of corporate bonds, they are the most active traders in the corporate bond market, as documented by Cai, Han, Li, and Li (2019).

[6]Following the prior literature, we aggregate the CRSP share-class level information to fund-level.

[7]We follow the literature by including the inter-dealer trades when calculating this measure.

[8]Examples of papers using these liquidity measures for corporate bonds include Bao, Pan, and Wang (2011), Dick-Nielsen, Feldhütter, and Lando (2012), Feldhütter (2012), Bao and Pan (2013), Jiang, Li, and Wang (2020), Cai, Han, Li, and Li (2019), and Kargar, Lester, Lindsay, Liu, Weill, and Zuniga (2020).

data of our sample funds, based on bonds' 8-digit CUSIP. About 75% of bond holding data in our sample funds are matched with our bond data set.

2.2 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 literature suggests that a mutual fund holding a substantial amount of illiquid bonds may be prone to large investor redemptions upon negative shocks, which in turn may trigger the fund to liquidate its bond holdings. Hence, when a particular bond is held primarily by illiquid mutual funds, the fragility in these funds is likely spilled over to the bond.

As such, we use a two-step procedure to construct mutual fund asset illiquidity-based bond fragility measure. First, we assign an "illiquidity score" to each fund based on the par amount of holding-weighted average of bond illiquidity within that fund,

$$Fund\ Illiquidity_{j,t}^{type} = \frac{\sum_{i=1}^{I} Holding\ Amount_{j,i,t} \times Bond\ Illiquidity_{i,t}^{type}}{\sum_{i=1}^{I} Holding\ Amount_{j,i,t}}, \tag{2.1}$$

where $Bond\ Illiquidity_{i,t}^{type}$ is the illiquidity measure of bond i in quarter t with type being either "Amihud", "IRC", or "Spread", and $Holding\ Amount_{j,i,t}$ is the par amount of corporate bond i held by mutual fund j as of the end of quarter t. This fund-level illiquidity score reflects the overall liquidity condition of a mutual fund's corporate bond holdings. We find that funds with higher illiquidity score tend to earn higher net returns, have less portfolio turnover, post a higher expense ratio, and experience higher return volatility over the next 2 years.

Second, we compute the bond-level fragility measure based on the weighted-average "illiquidity scores" of investing funds, where the weights commensurate with funds' relative presence in the bond, as

$$Fragility_{i,t}^{type} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Illiquidity_{j,t}^{type}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}}, \tag{2.2}$$

where $Fund\ Illiquidity_{j,t}^{type}$ is the "illiquidity score" of fund j in quarter t with type being either "Aminud", "IRC", or "Spread", as defined by equation (2.1), and $Holding\ Amount_{j,i,t}$ is the par amount of corporate bond i held by mutual fund j at the end of quarter t.

2.3 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 $570 million, with time to maturity of about 8.6 years, a coupon rate of 6%, a credit rating of BBB,[10] and a turnover rate of 16% within a quarter. The average return (annualized) of our sample bond is 8%, and the standard deviation of annualized weekly returns within a quarter is 10%.

The average bonds illiquidity measure based on Amihud is 0.06% per thousand dollars, which implies an average price impact of 1.50% for a median trade size of $25,000. The average illiquidity based on IRC and same-day bid-ask spreads is 0.90%, and 1.16%, respectively. The distribution of bond illiquidity measures are all right-skewed, with larger means than medians. Meanwhile, the average bond's fragility measures calculated from its investing mutual funds' asset illiquidity are 0.05% per thousand dollars based on Amihud, 0.78 based on IRC, and 0.91 based on same-day bid-ask spreads.

Panel B of Table 1 shows that the three illiquidity measures of corporate bonds (Amihud, IRC, and Spread) are reasonably correlated, with pair-wise correlations ranging from 0.35 to 0.62. In addition, bond illiquidity measures and holding-based fragility measures are positively correlated, with pair-wise correlations ranging from 0.32 to 0.59.

3 Baseline Results

In this section, we investigate whether mutual fund asset illiquidity-induced fragility affects bond return volatility, using our full sample from 2006:Q1 to 2020:Q1. We then test if mutual fund selling pressures may be an underlying force driving the link.

[9] A detailed list of variable definitions is provided 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.

3.1 Predictive Power of Fragility Measures for Bond Return Volatility

The excess volatility of corporate bonds has attracted broad attention.[11] We hypothesize that the significant liquidity mismatch faced by open-end bond mutual funds may contribute to excessive price movements for individual bonds. In particular, we test whether our bond fragility measures, which reflects potential adverse impact stemming from liquidity mismatch of their corporate bond mutual fund holders, have significant explanatory power for bond return volatility after controlling for known factors contributing to volatility.

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

$$Return\_SD_{i,t+1} = \alpha + \beta Fragility_{i,t}^{type} + \theta Controls_{i,t} + \mu_t + \epsilon_{i,t+1}. \tag{3.1}$$

$Return\_SD$ 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 $thousand), 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, stock volatility for the bond's corresponding company, and the fraction of the bond's outstanding amount held by mutual funds. Standard errors are two-way clustered at the bond and quarter levels.

Table 2 shows several key results. First, Columns (1)–(3) show that the coefficients of bond fragility measures based on all three liquidity measures are significantly positive, in the presence of lagged bond illiquidity measures and other variables known to predict bond volatility. Second, the

[11] Bao and Pan (2013) examine potential drivers for volatility from both firm fundamental and trading illiquidity perspectives. Bao, Chen, Hou, and Lu (2018) document a strong positive cross-sectional relation between corporate bond yield spreads and bond return volatilities. Bai, Bali, and Wen (2019) find a significantly positive relation between volatility and corporate bond returns. Chung, Wang, and Wu (2019) examines the pricing of volatility risk and idiosyncratic volatility in the cross-section of corporate bond returns.

[12] Our bond fragility measure, by construction, may reflect to some degree its own illiquidity measure. Consider an extreme case where a corporate bond is held by only one mutual fund, which happens to invest 100% of its bond portfolio on this bond. In this scenario, the bond's fragility measure, by definition, would be the same as its liquidity measure. Such case, however, is near impossible, as our sample funds on average hold about 150 corporate bonds, and our sample corporate bond on average is held by 30 mutual funds. To address any remaining concern on a potential mechanic link between fragility and bond illiquidity, we control for the bond's own illiquidity measures in all regressions whenever fragility measures are used as an independent variable.

economic significance of the predicting power is also sizable. For instance, one standard deviation increase in Amihud_based bond fragility is associated with an increase of $0.3831 \times 0.03 = 1.15\%$ in the annualized bond return volatility over the next quarter, about 16% 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 $0.1206 \times 0.09 = 1.09\%$ in bond volatility. Third, the predicting power of fragility for bond return volatility is robust to controlling for the bond fixed effect (Columns (4)–(6)).[13] In addition, We examine an alternative specification by including bond's lagged volatility as a control variable and excluding bond fixed-effect. Our findings, shown in Internet Appendix Table IA.1, are robust to this alternative specification. In sum, these results suggest that bond fragility arising from asset illiquidity of its investing funds affects corporate bond volatility in a significant way that is beyond the usual mechanisms documented in the existing literature.

Other control variables are shown to affect 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 performance, and longer time-to-maturity, appear to subsequently experience higher return volatility. Moreover, 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, consistent with the findings in Fleming, Kirby, and Ostdiek (1998). Finally, there is 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.

Corporate bonds with high-yield credit ratings (i.e., junk bonds) are riskier, less liquid, and generally display higher volatility than their investment-grade counterparts.[14] Hence, we hypothesize a potentially more prominent impact by fragility on bond price movements among high-yield bonds. To explore along this, we separately examine the impact of fragility for investment-grade and high-

[13] To reduce the 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).

[14] The high-yield corporate bond sector is shown to go through major meltdowns every few years, which often coincide with economic slowdowns. See, for example, a report by New York Times: High-Yield Bonds Have Been Behaving a Lot Like Stocks.

yield bonds.[15] Results in the Internet Appendix Table IA.2 show that while our fragility measures significantly predict future bond volatility across the credit spectrum, the statistical significance and the economic magnitude of such effect is much higher among high-yield bonds. In general, the coefficients of the fragility measures are 2-5 times higher for the high-yield bonds subsample than their investment grade counterparts. The results corroborate our conjecture that fragility may play a more visible role affecting price movements among bonds with lower credit ratings.

3.2 Fleshing out the Mechanism: Mutual Fund Selling Pressure

The preceding results support the notion that the asset illiquidity of mutual funds generates fragility, which spills over into the assets they hold. This subsection aims to shed light on the underlying mechanism.

We hypothesize that a plausible transmission channel for fragility to affect future bond volatility is through mutual funds' flow-induced selling pressures in the corporate bond market: When negative shocks prompt investors to pull money out of illiquid corporate bond funds, the redemption-driven selling pressure can depress corporate bond prices temporarily, which are likely to rebound once pressure wanes, hence leading to higher return volatility. To investigate this mechanism, we conduct two sets of analyses.

We start by examining whether bonds with higher fragility are more likely to be subject to future mutual fund selling pressure. The fragility measure is designed to capture the illiquidity of investing funds' corporate bond holdings, which has two implications on bond's future selling pressure. First, for funds with more illiquid holdings, negative shocks can trigger larger outows (see Goldstein, Jiang, and Ng (2017)); as such, bonds held by illiquid funds are likely to experience stronger flow-induced selling pressures. Second, corporate bond funds tend to follow a liquidity pecking order, selling liquid corporate bonds first to meet investor redemptions (see Jiang, Li, and Wang (2020)). Consider two bonds with similar liquidity, one is held by funds with a large amount of liquid assets, while the other is held by funds with mainly illiquid assets. Even when their investing funds face a similar amount of redemption requests, the bond held by liquid funds is less likely to be sold because its investing funds can tap into other liquid holdings first. Taking

[15] 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.

into consideration the two effects, we would expect higher odds of a bond being liquidated amid redemptions if the bond is held by illiquid funds.

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

$$Sell\ Pressure_{i,t} = \frac{\sum_{j=1}^{J}(Sell\ Amt_{j,i,t}|Flow_{j,t} < 25^{th}\ Pctl - Buy\ Amt_{j,i,t}|Flow_{j,t} > 75^{th}\ Pctl)}{Amount\ Outstanding_{i,t}}. \quad (3.2)$$

This measure captures the difference between sales and purchases of bonds by mutual funds that experience extreme outflows and inflows, respectively, with a large positive (negative) value indicating strong selling (buying) pressure. With it, we perform the following quarterly regression of the selling pressure measure in quarter $t+1$ on fragility in quarter t:

$$Sell\ Pressure_{i,t+1} = \alpha + \beta Fragility_{i,t}^{type} + \theta Controls_{i,t} + \mu_t + \epsilon_{i,t+1} \quad (3.3)$$

A set of fund characteristics is controlled for, including bond illiquidity measures, 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, stock volatility for the bond's corresponding company, and the fraction of the bond's outstanding amount held by mutual funds. We also include time fixed effect for all specifications. Standard errors are two-way clustered at the bond and quarter levels.

Table 3 reports the regression results, with Columns (4)–(6) further controlling for bond fixed effect. All three fragility measures are shown to have significantly positive impact on future flow-induced sales, suggesting that bonds with higher fragility are more likely to be liquidated by mutual funds when the funds experience large outflows. This is impressive given that fragility is an unsigned variable ex-ante, yet fire sales is directional. The economic impact on selling pressure due to fragility is large. Take Column 4 as an example: one standard deviation increase in Amihud-based fragility measure is associated with an increase in selling pressure of $0.03 \times 0.032 = 0.001$ (11% of the standard deviation). Moreover, in Internet Appendix Table IA.3, we show that fragility has incremental forecasting power for future selling pressure even after we control for the lagged selling pressure. Overall, the results support the notion that a bond is more likely to be liquidated by funds amid redemptions when its investing funds' overall corporate bond holdings are relatively less liquid.

To enrich our understanding on the predicting power of fragility on bond selling pressure, we consider two additional measures to capture bond selling pressures. One measures the relative scope of investing funds experiencing outflows, based on the difference between the number of investing funds that experience subsequent outflows and that experiencing inflows over the next quarter. The other captures the selling intensity, based on the average selling amount across investing funds with large outflows and defined as:

$$\frac{\sum_{j=1}^{J}(Sell\ Amt_{j,i,t+1} \times \mathbf{1}(Flow_{j,t+1} < 25^{th}\ Pctl))/\sum_{j=1}^{J}\mathbf{1}(Flow_{j,t+1} < 25^{th}\ Pctl)}{Amount\ Outstanding_{i,t}}, \qquad (3.4)$$

where $Sell\ Amt_{j,i,t+1}$ is the par amount of corporate bond i sold by mutual fund j in quarter $t+1$. $\mathbf{1}(Flow_{jt+1} < 25^{th}\ Pctl)$ is an indicator variable that equals one if flow of mutual fund j in quarter $t+1$ ranks the bottom 25% among all funds in the quarter. We replace $Sell\ Pressure$ with these two measures and re-estimate Equation (3.3) with the same control variables. Standard errors are clustered at the bond and quarter levels.

Internet Appendix Table IA.4 show estimation results on our key variables. Columns (1)–(3) show that for two out of three specifications, bonds with higher fragility tend to have a higher number of investing funds experiencing outflows than inflows in the next quarter. Columns (4)–(6) indicate that for all three specifications, bonds with higher fragility tend to be sold by larger amounts by their investing funds to meet large redemption requests. Such associations are statistically significant and economically strong.

In sum, the above analyses not only shed light on the underlying mechanism of our main results, but also highlight our contribution to the fire-sale literature. In particular, our analyses suggest a potential contributing factor to fire sale that arises from mutual fund asset illiquidity.

In our second set of analyses, we examine whether the mutual fund flow-induced selling pressure leads to significant price movement. The existing literature has documented evidence for the price impact of mutual fund flow-induced trades for equity market,[16] which points to a subsequent return reversal when the price pressure ebbs away. However, the evidence in the corporate bond market is

[16] See, for examples, Coval and Stafford (2007), Frazzini and Lamont (2008),

mixed.[17] If the volatility predicting power by fragility arises from the mutual fund fire sale pressure, we would expect bonds with higher selling pressure to experience immediate price drops which are reversed subsequently.

To investigate this issue, we perform the regression of abnormal bond returns over the concurrent quarter and over the next 1^{st}, 2^{nd} and 3^{rd} month on the selling pressure measure, as follows:

$$AbReturn_{i,t+k} = \alpha_k + \beta_k Sell\ Pressure_{i,t} + \theta_k Controls_{i,t} + \mu_t + \phi_i + \epsilon_{i,t+k}, k = 0, 1, 2, 3 \quad (3.5)$$

Abnormal return is as annualized bond return subtracted by the size-weighted average return of the pool of bonds that share similar credit ratings and time to maturity 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 bonds' turnover, rating, amount outstanding, maturity, mutual fund ownership as well as the issuers' stock volatility. Time-fixed and bond-fixed effects are also controlled for.

Column (1) of Table 4 shows that when bonds with higher selling pressure in quarter t tend to earn lower abnormal returns during the same quarter. However, as pressure abates over the following months, bond prices rebound, leading to significantly higher abnormal returns, as shown in Columns (3)–(4). Overall, the results suggest that mutual funds' redemption-induced selling pressures lead to notable price movements and higher return volatility. Such findings, together with our earlier results showing a positive link between fragility and selling pressure, provide support to the hypothesis that mutual fund selling pressure may serve as the underlying mechanism driving the link between fragility and bond volatility.

4 Impact of Fragility at Times of Stress

So far, we have documented a strong volatility predicting power by our fragility measures, and shown mutual funds' flow-induced selling pressure as a likely underlying driver. We conjecture that such patterns may intensify at times of stress, when the corporate bond market is more volatile, less

[17] Jiang, Li, and Wang (2020) and Cai, Han, Li, and Li (2019) find evidence of price impact of mutual fund trading, which was reversed afterwards. However, Choi, Hoseinzade, Shin, and Tehranian (2020) find no evidence for price impact of mutual fund fire sales.

liquid, and redemption-induced fire sales from mutual funds are more prevalent. In this section, we explore whether the impact of fragility on price movements may be contingent on market conditions.

4.1 The Case of Covid-19 Crisis

First, we focus on the Covid-19 crisis period around March 2020, during which the corporate bond market experienced extraordinary price movements (see Figure 1) and bond mutual funds suffered substantial outflows.[18]

The Covid-19 crisis episode provides an ideal setting to perform a thorough anatomy of how fragility, measured at the end of 2019, affected bond price dynamics during the market turmoil. First, the crisis started with mounting concerns about the pandemic and quickly spiraled into a full-blown liquidity turmoil within a couple of weeks, with bond mutual funds facing soaring investor redemption and forced to sell their holdings of corporate bonds. Under the mutual fund redemption-induced selling pressure mechanism, one would expect the effect of our latent fragility arising from fund asset illiquidity to be amplified in this episode. Second, the Federal Reserve intervened with the announcement of the unprecedented Secondary Market Corporate Credit Facility (SMCCF) on March 23, 2020, which effectively normalized the corporate bond markets within a couple of weeks. This provides an opportunity to study if bonds with higher fragility levels would benefit more from the Federal Reserve's intervention and exhibit stronger price rebound.

Given the short span of the crisis, we switch to a weekly panel regression setup to examine whether bonds with different pre-crisis fragility measures experienced different price dynamics around the height of the crisis and following the Federal Reserve intervention. First, we estimate a weekly panel regression from the start of 2020 to March 21, as follows:

$$Return_{i,t+k} = \alpha + \gamma Fragility_{i,t}^{type} + \eta Crisis_{t+k} + \beta Crisis_{t+k} \times Fragility_{i,t}^{type} + \theta Control_{i,t} + \epsilon_{i,t+k} \quad (4.1)$$

The dependent variable is weekly corporate bond returns, in decimal, and the independent variables include *Fragility* at the end of 2019Q4, and its interaction term with *Crisis*, a dummy variable that equals one for the four weeks before the Federal Reserve announced the establishment of

[18] See, for example, a report by Financial Times: Have investment funds averted a liquidity crisis?

the SMCCF, (i.e., the last week in February and the first three weeks in March). The control set consists of *Illiquidity* and its interaction term with *Crisis*, as well as turnover, credit rating, natural log of the outstanding amount of the bond in thousands of dollars, coupon rate, natural log of number of months until bond maturity, and the fraction of the bond's outstanding amount held by mutual funds, as of the end of 2019Q4. Standard errors are clustered at the bond level.[19]

Table 5 shows the results on key variables, with estimation results on other variables omitted for brevity. First, coefficient on *Fragility* is positive and significant in all specifications, indicating that bonds with higher fragility on average earned higher returns outside the four week's of crisis period in 2020Q1, potentially to compensate for bearing higher fragility risk.

More importantly, the interaction term of *Fragility* with *Crisis* is significantly negative, suggesting that bonds with high latent fragility indeed suffered a bigger blow in their valuation during the four-week Covid-19 crisis period: one standard deviation increase in fragility is associated with a drop in weekly return (not annualized) from its pre-crisis period by about 1 percentage point.[20] The economic significance of the impact by fragility on bond returns during the crisis compares favorably with that by bond illiquidity: While the interaction term of *Illiquidity* with *Crisis* is also significantly negative, consistent with the notion that illiquid bonds tend to be particular vulnerable during crisis period, one standard deviation increase in illiquidity is associated with a drop in weekly return from its pre-crisis levels by 0.3-0.6 percentage point, a notably smaller effect compared to that due to fragility.[21] Adding controls for week fixed effect does little change on our main results, shown in Columns (4)–(6).

On March 23, 2020, as part of a wide array of measures aimed at providing liquidity and supporting economy, the Federal Reserve announced the establishment of the SMCCF. Within days of the initial SMCCF announcement, stresses in the corporate bond market began to ease, and corporate bond funds and ETFs started to see reversals in investor flows. Under the mutual fund fire sale mechanism, corporate bonds with higher fragility levels and experienced sharper price drops

[19]Given the limited number of weeks in this period, we focus on the specification with standard errors clustered at the bond level. The results where standard errors are clustered at both the bond and week levels, available upon request, yield qualitatively same patterns.

[20]One standard deviation increase in *Fragility_Amihud*, *Fragility_IRC*, and *Fragility_Spread* is associated with a drop in weekly return from its pre-crisis period by 1.09% (1.086×0.01), 1.04% (0.104×0.10), and 0.94% (0.078×0.12), respectively. Note that the standard deviations of fragility measures are re-calculated based on the 2019Q4 observations, and are 0.01 (*Fragility_Amihud*), 0.10 (*Fragility_IRC*), and 0.12 (*Fragility_Spread*).

[21]One standard deviation increase in *Amihud*, *IRC*, and *Spread* is associated with a drop in weekly return from its pre-crisis period by 0.3% (0.056×0.06), 0.4% (0.009×0.42), and 0.6% (0.010×0.64), respectively.

over the Covid-19 crisis period are expected to exhibit a stronger rebound amid waning pressure. To investigate along this line, we conduct a weekly panel regression around the announcement of the SMCCF, as follows:

$$Return_{i,t+k} = \alpha + \gamma Fragility_{i,t}^{type} + \eta SMCCF_{t+k} + \beta SMCCF_{t+k} \times Fragility_{i,t}^{type} + \theta Control_{i,t} + \epsilon_{i,t+k} \quad (4.2)$$

The sample includes a window of two weeks before and two weeks after the March 23 announcement of SMCCF.[22] The dependent variable is weekly corporate bond returns, in decimal, and the independent variables include $Fragility$ at the end of 2019Q4, and its interaction term with $SMCCF$, a dummy variable that equals zero for the two weeks before the SMCCF announcement, and equal one for the two weeks after the announcement. The control set is the same as in Equation (4.1). Standard errors are clustered at the bond level.[23]

Table 6 shows the results on key variables, with estimation results on other variables omitted for brevity. First, coefficient on $SMCCF$ is significantly positive, suggesting that bonds in general benefit from the Fed's announcement to unprecedentedly intervene directly in the corporate bond markets. More importantly, the interaction term of $Fragility$ with $SMCCF$ is strongly positive, suggesting that bonds with higher latent fragility exhibited a stronger rebound in valuation when acute market stress abated following the SMCCF announcement. In particular, one standard deviation increase in fragility is associated with an increase in post-intervention weekly return by 1.3–1.7 percentage points.[24] In comparison, one standard deviation increase in illiquidity is associated with an increase in post-intervention weekly return by 0.2–0.8 percentage point, more muted than that due to fragility.[25]

We conduct similar analyses on bond yield spreads, with the dependent variables in Equations (4.1) and (4.2) replaced with weekly changes in yield spreads.[26] Key results, reported in Internet

[22] For robustness, we also consider a window of four weeks before and four weeks after the SMCCF announcement, and results, available upon request, remain qualitatively the same.

[23] Given that there are only four weeks in this regression, we do not double cluster on the standard errors. Our main results remain valid with a double-clustering specification at the bond and week levels.

[24] One standard deviation increase in $Fragility\_Amihud$, $Fragility\_IRC$, and $Fragility\_Spread$ is associated with an increase in post-intervention weekly return by 1.7% (1.697×0.01), 1.5% (0.147×0.10) and 1.3% (0.111×0.12), respectively.

[25] One standard deviation increase in $Amihud$, IRC, and $Spread$ is associated with an increase in post-intervention weekly return by 0.2% (0.031×0.06), 0.5% (0.012×0.42), and 0.8% (0.012×0.64), respectively.

[26] Yield spreads of corporate bonds are defined as the difference between corporate bond yields and the Treasury

Appendix Tables IA.5 and IA.6, show that yield spreads of bonds with higher latent fragility widened significantly more over the crisis, and narrowed more over the post-intervention period, consistent with the results based on weekly returns.

To summarize, our analyses on bond price resilience around the Covid-19 crisis indicate that bonds with higher latent fragility experienced lower returns during the crisis, and exhibited larger rebound subsequently. These findings provide direct illustration on how fragility measures drive up bond return volatility from a "decomposed-volatility" perspective. Moreover, these findings highlight the potential for our fragility measures to serve as strong pre-crisis indicators for future price vulnerability at the individual bond levels.

4.2 A Full Sample Analysis

In light of the strong predictive power of fragility measures on bond price dynamics during the Covid-19 crisis, it is natural to investigate whether our fragility measures have a more salient impact on bond price volatility at times of market stress. To that end, we revert to our quarterly sample from 2006Q1 to 2020Q1 and use a battery of aggregate measures, calculated from both financial markets and real economic activities, to capture market stress and aggregate uncertainties.

Our first proxy for financial market stress is CBOE volatility index (VIX). Goldstein, Jiang, and Ng (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, Li, and Wang (2020) further show that when meeting redemptions amid high VIX, corporate bond funds tend to sell illiquid corporate bonds more aggressively, and such selling pressures are shown to lead to temporary movements in corporate bond prices. The evidence, together, suggests a potentially stronger spillover effect from redemption risks faced by bond funds, to bond price vulnerability over high-VIX periods.

We use a similar specification as in the baseline model, while adding an interaction term between fragility measures and VIX, as well as an interaction term between illiquidity measures and VIX. In particular, we conduct the following regression estimation:

$$Return\_SD_{i,t+1} = \alpha + \gamma Fragility^{type}_{i,t} + \beta Fragility^{type}_{i,t} \times VIX_{t+1} + \theta Controls_{i,t} + \mu_t + \epsilon_{i,t+1}, \quad (4.3)$$

bond yields of comparable maturity.

where VIX_{t+1} is calculated as within-quarter average level in quarter $t+1$. Panel A of Table 7 summarizes the estimation results on the key variables. All the bond characteristics in Equation (3.1) are controlled for but not reported in the table for brevity. Time fixed effects are included for all specifications, and bond fixed effects are included for Columns (4)–(6). In general, the predicting power of fragility measures increases with the level of VIX, as the interaction term of $Fragility$ with VIX exhibits a significantly positive effect on bonds' future volatility for two out of three fragility measures. Taking Column (2) as an example, for a bond with a median level of IRC-based $Fragility$, a one standard deviation increase in VIX leads to $0.0025 \times 0.74 \times 7.94 = 0.01469$ increase in subsequent volatility, about 20% of the median level of bond volatility.

Next, we adopt a measure based on flight-to-safety (FTS) days (Baele, Bekaert, Inghelbrecht, and Wei (2020)) to gauge the level of market stress and aggregate uncertainties. Baele, Bekaert, Inghelbrecht, and Wei (2020) identifies FTS days based on aggregate stock and bond returns, and shows that while FTS days only account for about 3% of observations in the U.S. markets, they are associated with notable impact on risk premium, return, and volatility of major asset classes, as well as on future real economic activities; in addition, U.S. corporate bond mutual fund investors are shown to actively redeem their shares in response to FTS effects. Therefore, we explore whether there is a stronger impact of $Fragility$ on bond volatilty around the FTS incidents.

To do this, We conduct a similar quarterly panel regression as in Equation (4.3) while replacing VIX with fraction of FTS days in quarter $t+1$, denoted as FTS. The key results, summarized in Panel B of Table 7, indicate that the volatility predicting power of $Fragility$ generally becomes more prominent around the FTS incidents. For instance, Column (1) suggests that for a given bond with median level of Amihud-based $Fragility$, one standard deviation increase in FTS leads to $1.1778 \times 0.04 \times 0.07 = 0.0033$ increase in subsequent volatility, about 5% of the median level of bond volatility.

We then move to capture market stress and macroeconomic uncertainty using indicators from real economic activities. The first proxy is the Smoothed U.S. Recession Probabilities retrieved from FRED, Federal Reserve Bank of St. Louis; and the second is the Chicago Fed National Activity Index (CFNAI), an index designed to gauge overall economic activity and related inflationary pressure with a positive index reading corresponding to growth above trend. We replace the financial market-based stress variables in Equation (4.3) with these real economic measures, and present the key regression results in Table 8. Consistent with the previous results based on financial indicators, the interaction terms between fragility measures and real economic measures generally attract a significantly positive coefficient in Panel A (using recession probability) and a negative coefficient in Panel B (using CFNAI),[27] suggesting a stronger impact of our fragility measures on bond volatility at times of real economic downturns.

In sum, we use a variety of aggregate measures to proxy for market stress and economic downturns, from the perspective of market volatility, fund flows, recession probability, and economic growth, and find consistent evidence that our fragility measures have stronger prediction powers on bond price movements during times of market stress. This finding, together with the analyses on the Covid-19 crisis, lends strong support for the fragility measures to be considered as an effective pre-crisis indicator for bond price resilience during a potential crisis.

5 Further Discussions

In this section, we provide a battery of analyses to deepen our understanding of how mutual fund asset illiquidity might shape the behavior of corporate bond prices. First, we conduct analyses exploring the asset pricing implication of our fragility measures. Second, we examine whether liquidity commonality could serve as an alternative interpretation for our findings. We then examine whether information asymmetry may provide another channel for fragility to affect bond volatility. Finally, we investigate whether other liquidity aspects of investing funds' portfolios may affect the effect of latent fragility.

5.1 Asset Pricing Implications of Fragility

Our analyses have shown strong evidence that latent fragility can predict excessive movements of bond prices, especially at times of market stress. In light of these results, it is plausible that bond market participants may require higher returns on bonds with higher fragility. In this subsection, we examine whether our fragility measures predict cross-sectional variation of future bond returns. Specifically, we run a panel regression as follows:

$$AbReturn_{i,t+1} = \alpha + \beta Fragility_{i,t}^{type} + \theta Controls_{i,t} + \mu_t + \epsilon_{i,t+1}, \tag{5.1}$$

[27]Note that CFNAI should be interpreted as the negative of a stress measure.

where $AbReturn_{i,t+1}$ is defined as the bond's abnormal return over quarter $t+1$ relative to the contemporaneous value-weighted average return of all corporate bonds of similar ratings and time-to-maturity. We control for a battery of variables that could potentially contribute to bond future returns, including previous quarter's bond illiquidity measures, abnormal returns, return volatility, turnover, rating, amount outstanding,coupon rate, time to maturity, issuers' stock volatility as well as fraction of bonds held by mutual funds. We also control for time fixed effect in all specifications. Standard errors are two-way clustered at the bond and quarter levels.

Table 9 reports the regression results, with bond fixed effect further controlled for in Columns (4)–(6). The coefficients of the fragility measures are positive for all specifications, and are statistically significant for three out of the six specifications. Note that we construct the fragility measures by integrating two pieces of information: how illiquid a fund's overall bond portfolio is, and how large this fund's position in a given bond. These measures contain little information regarding the fundamentals of the specific bond, yet it does a decent job predicting bond returns in the presence of other price-based variables such as volatility and illiquidity. These findings suggest that beyond concerns for bond fundamental, illiquidity and volatility, bond investors require additional compensation for holding high fragility bonds.

Having detected a return predicting power by the latent fragility, we move to investigate whether fragility may also contribute to the cross-sectional variations in yield spreads. Identifying yield spread determinants is of fundamental importance from both investment and corporate finance perspectives. Recent literature shows that bond-level credit ratings, illiquidity and return volatility all play important roles in driving cross-sectional variation in yield spread with large economic significance.[28] We investigate whether our fragility measures provide additional insight in understanding yield spread determinants.

Given the high persistence in the levels of yield spread, we conduct a quarterly panel regression, regressing changes in quarter-end yield spreads from quarter $t-1$ to t, in percent, on contemporaneous quarterly changes in fragility measures and control variables, as follows:

$$\Delta Yield\ Spread_{i,t} = \alpha + \beta \Delta Fragility_{i,t}^{type} + \theta \Delta Controls_{i,t} + \mu_t + \epsilon_{i,t}. \tag{5.2}$$

[28] See, for instance, Huang and Huang (2012), Chen, Lesmond, and Wei (2007), Bao, Pan, and Wang (2011), and Bao, Chen, Hou, and Lu (2018)

Control variables include contemporaneous quarter's bond illiquidity measures, abnormal returns, return volatility, turnover, rating, amount outstanding, time to maturity, issuers' stock volatility as well as fraction of bonds held by mutual funds. Results on key variables are shown in Table 10. The coefficient of $\Delta Fragility$ is significantly positive for four out of six specifications, indicating that higher fragility is generally associated with higher yield spreads. The effect of fragility measures on yield spreads is also economically significant. For instance, Column (2) shows that one standard deviation increase in the change of the IRC-based fragility measure is associated with a $1.311 \times 0.1 = 0.131\%$ widening in yield spreads.

Collectively, our evidence indicates that the fragility measures, which reflect investing fund's overall asset illiquidity, have some pricing implications for individual bonds, even after controlling for a battery of factors known to predict bond returns and yield spreads.

5.2 Liquidity Commonality as an Alternative Interpretation?

In this subsection, we discuss whether liquidity commonality could serve as an alternative interpretation for our findings. Bao, Pan, and Wang (2011) show that there is a substantial commonality in the time variation of corporate bond illiquidity. The co-movement in illiquidity implies that, for a given bond, the aggregate liquidity level of other bonds held in its investing funds' portfolio could contain incremental information about the bond's future liquidity, and thus price volatility, on top of the bond's own liquidity level. Since our fragility measure is based on funds' portfolio liquidity, one could potentially argue that the documented volatility predicting power by our fragility measures merely reflects the influence of liquidity commonality.

To assess this validity of alternative interpretation, for each bond, we first estimate its illiquidity beta through a rolling weekly regression of the bond's liquidity on the average liquidity of all corporate bonds in the market over the past 12 months.[29] The rolling window regression allows for the estimated illiquidity beta to vary over time as bonds' liquidity commonality may vary with the market condition. The higher the illiquidity beta of a bond, the more likely the bond's illiquidity co-moves with the other bonds' illiquidity.

If liquidity commonality drives our findings, we would expect that controlling for illiquidity

[29]Since the liquidity beta estimation tends to be noisy, we use a relatively longer window to estimate it to minimize the estimation errors. We also estimate the liquidity beta using 6-month time window and our results are qualitatively similar.

beta will lead to weakened volatility predicting power by our fragility measures. Thus, we add the illiquidity beta to the control set of the baseline model (3.1), and report results in Table 11. First, we see that both the level of illiquidity and the illiquidity beta are positively and significantly associated with future bond return volatility. Second and more importantly, the fragility measures maintain their significant forecasting power toward future bond volatility even in the presence of bonds' illiquidity beta. The levels of economic significance are also similar to the ones in Table 2. For example, a one-standard deviation increase in the Amihud-based fragility measure is associated with an increase of $0.38 \times 0.03 = 1.14\%$ in the annualized bond return volatility in the next quarter. These results provide evidence that the strong predicting power by fragility toward bond return volatility is unlikely attributed to liquidity commonality.[30]

To address the remaining concern that liquidity commonality might be more prevalent in times of stress, we next move to examine if liquidity commonality could explain the heightened impact of fragility on bond price movements during the Covid-19 crisis. We repeat the regression analysis as in model (4.1) but include illiquidity beta and its interaction term with the crisis dummy as additional control variables. Shown in Internet Appendix Table IA.7, bonds with higher illiquidity beta experienced larger drops in bond prices during the crisis period, as expected. More importantly, the forecasting power associated with the fragility measures remains qualitatively the same.[31]

Overall, the results in this subsection show that even though liquidity commonality affects bond price movements, it does not subsume the strong impact of fragility, both for the full-sample and in the Covid-19 crisis analyses. Thus, our findings do not support liquidity commonality as the alternative explanation for our results.

5.3 Information Asymmetry as Another Channel?

Another potential channel driving our main results is through information asymmetry. It is possible that mutual funds self-select into holding bonds with varying degrees of information asymmetry.

[30] As an alternative way to control for liquidity commonality, in an unreported test, for each bond, we also calculate the average liquidity of all other bonds with similar ratings and maturities. We find that the fragility measures continue to pertain significant forecasting power toward future bond volatility after controlling for this alternative liquidity commonality measure.

[31] We also examine whether liquidity commonality could explain the stronger response to Fed's intervention for bonds with higher fragility. In Internet Appendix Table IA.8, we repeat the analysis as in model (4.2) but also control for illiquidity beta and its interaction term with the SMCCF dummy. We continue to find that bonds with higher fragility experienced stronger rebounds after the Fed's intervention.

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.[32] In light of this, the asset illiquidity of investing funds may be reflecting the information asymmetry conditions of the traded bonds, and the latter may drive up bond volatility.

To evaluate the validity of this mechanism, we examine the effect of fund asset illiquidity-induced fragility on intertemporal return behaviors. If bonds with higher fragility measures tend to be held by informed investors, their price changes will more likely be driven by informed trades. The literature generally agrees that when a subset of investors trade a security for information reasons, that information is usually only partially incorporated into current prices, and the low (high) return in the current period tend to be followed by low (high) return in the next period (e.g., Llorente, Michaely, Saar, and Wang (2002)). Therefore, under the information asymmetry channel, bonds with higher fund fragility are likely to experience a stronger return continuation pattern. 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.

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

$$\begin{aligned} AbReturn_{i,t+k} = \alpha_k + \beta_k AbReturn_{i,t} \times Fragility_{i,t}^{type} + \gamma_k Fragility_{i,t}^{type} + \eta_k AbReturn_{i,t} \\ + \theta_k Control_{i,t} + \mu_t + \epsilon_{i,t+k}, \ k = 1, 2, 3, \quad (5.3) \end{aligned}$$

where $AbReturn_{i,t+k}$ represents abnormal return (relative to the group of bonds with similar ratings and time to maturity) of bond i in the k-th month after quarter t. For independent variables, in addition to fragility measures and their interaction terms with current abnormal return, we also include illiquidity measures and their interaction terms with abnormal return. Other controls include bond turnover, rating, amount outstanding, coupon rate, time to maturity, same-firm stock volatility, mutual fund ownership, as well as time fixed effect.

[32]See e.g. Fecht, Füss, and Rindler (2014) and Benmelech and Bergman (2018)

Columns (1) to (3) of Table 12 show that using Amihud-based fragility measure, we detect a strong return reversal pattern for bonds with high fragility: the coefficient on the interaction term of lagged bond return and fragility is significantly negative for up to the next three months. Using IRC- and spread-based fragility measures, we find similar return reversal patterns, as in Columns (4)–(6) and (7)–(9), respectively.

These results show that bond fragility measures in general intensify future return reversals for corporate bonds, which are in supportive of a mutual fund-induced selling pressure mechanism, but not the information asymmetry story.

5.4 Fragility Mitigated by Fund Liquidity Buffers?

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 bonds a fund holds, the more acute the liquidity mismatch concerns will be. Nevertheless, such concerns could be alleviated when funds have some liquidity buffers, as documented by Chernenko and Sunderam (2016) and Choi, Hoseinzade, Shin, and Tehranian (2020). In particular, when fund managers face outflows, they can first resort to cash or the selling of liquid assets (like government securities) to meet the redemption needs. Hence, it is useful to investigate whether funds' liquid asset holdings could mitigate the adverse impact of fund illiquid asset holdings on bond price volatility.

To that end, we construct a bond-level *Liquid Holding* measure by aggregating liquid asset holdings across investing funds, with weights commensurate with funds' relative presence among all investing funds in the bond:

$$Liquid\ Holding_{i,t} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Liquid\ Asset_{j,t}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}}, \tag{5.4}$$

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 $Fund\ Liquid\ Asset_{j,t}$ is the share of liquid asset holdings (cash and government securities) relative to total assets for fund j in quarter t. To mitigate the effects of misreporting in CRSP, we follow prior literature and restrict funds' cash holding to the range of 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).

We then include *Liquid Holding* and its interaction term with fragility measures to Model (3.1) as follows:

$$Return\_SD_{i,t+1} = \alpha + \gamma Fragility_{i,t}^{type} + \eta Liquid\ Holding_{i,t} + \beta Fragility_{i,t}^{type} \times Liquid\ Holding_{i,t} + \theta Controls_{i,t} + \mu_t + \epsilon_{i,t+1} \quad (5.5)$$

In addition to the control variables and fixed effects in the baseline Model (3.1), we also control for illiquidity measures and their interaction terms with *Liquid Holding*. Panel A of Table 13 shows the key results on the interaction term, with the rest of independent variables not reported in the table for brevity. For most of the specifications, the interaction terms are significantly negative, consistent with the hypothesis that funds utilize their liquid assets to absorb redemption shocks, thus alleviating the fragility concerns and reducing bond price fluctuations. For instance, Column (1) of Panel A shows that for a given bond with median level of Amihud-based *Fragility*, one standard deviation increase in *Liquid Holding* is associated with $1.1167 \times 0.04 \times 0.09 = 0.004$ decrease in bond volatility over the subsequent quarter, or 6% of the median volatility level. Meanwhile, all fragility measures still attract strongly positive coefficients (not shown).

Overall, our analysis suggests that fund asset illiquidity-induced fragility robustly affects bond return volatility, yet the adverse impact associated with fund illiquid holdings is partially offset by funds' liquidity buffers.

5.5 Fragility Intensified by Fund Allocation to Corporate Bonds?

One caveat with our fragility measure is that it does not distinguish between funds holding high fraction of corporate bonds asset class from those holding a low fraction. To address this issue, we construct a bond-level *Corp Holding* measure by aggregating asset allocation to corporate bond asset class across investing funds, with weights commensurate with funds' relative presence among all investing funds in the bond,

$$Corp\ Holding_{i,t} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Corp\ Asset_{j,t}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}}, \quad (5.6)$$

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 $Fund\ Corp\ Asset_{j,t}$ is the share of corporate bond asset holdings among all fixed-income assets for fund j in quarter t.[33] Therefore, a higher $Corp\ Holding$ indicates that on average the bond is held by funds that allocate their portfolios more towards corporate bonds.

We then include $Corp\ Holding$ and its interaction term with fragility measures to Model (3.1) as follows:

$$Return\_SD_{i,t+1} = \alpha + \gamma Fragility_{i,t}^{type} + \eta Corp\ Holding_{i,t} + \beta Fragility_{i,t}^{type} \times Corp\ Holding_{i,t} + \theta Controls_{i,t} + \mu_t + \epsilon_{i,t+1} \quad (5.7)$$

In addition to the control variables and fixed effects in the baseline Model (3.1), we also control for illiquidity measures and their interaction terms with $Corp\ Holding$. Panel B of Table 13 shows the results on the key interaction variables, with the rest of the independent variables not reported for brevity. For most of the specifications, the estimated coefficients on the interaction terms are significantly positive. This finding is consistent with the view that holding a higher fraction of illiquid corporate bonds intensifies mutual funds' liquidity mismatch problems, which could spill back to the assets these funds hold, leading to amplified fragility and higher volatility in bond prices.

6 Conclusion

Open-end mutual funds have grown to become a key player in the corporate bond market. They invest in illiquid bonds but provide daily liquid claims to shareholders. A growing literature shows that the liquidity transformation of mutual funds might generate a strong first-mover advantage among their investors in situations of adverse shocks, which leads to amplified redemption responses. As a result, fragility might emerge in the corporate bond mutual fund sector, especially among the funds holding more illiquid bonds.

In this paper, we ask the following question: does the asset illiquidity of mutual funds introduce fragility to the corporate bond market? To this end, we create a novel measure of latent fragility

[33] Other fixed-income holdings of bond mutual funds, based on the eMAXX data, include government securities, mortgage-backed securities, and asset-backed securities.

in individual corporate bonds based on the asset illiquidity of their mutual fund owners. We find that corporate bonds with higher fragility tend to experience higher future return volatility, after controlling for a rich set of bond characteristics such as credit rating, maturity, and bond illiquidity. Moreover, we find that redemption-induced mutual fund selling drives this relation. Using the Covid-19 crisis as a natural experiment, we find that corporate bonds with higher latent fragility at the end of 2019 experienced substantially more price drops during the crisis and greater rebounds after the Fed's intervention. We further provide evidence that our fragility measures in general have a larger impact on bond return volatility at times of market stress.

These results indicate that the fragility in open-end mutual funds spills over into the assets they hold, especially when they conduct considerable maturity transformation. We view our study as providing a novel analysis that illustrates the relation between the liquidity conditions of mutual funds and the dynamics of asset prices in the corporate bond market. It reveals ample future research opportunities. First, open-end mutual funds have expanded not only in the corporate bond market but in many other asset classes. It would be fruitful to extend this line of inquiry to other asset classes to fully understand the impact of asset managers' growing importance in asset markets. Second, in response to the growing concern about fragility in the mutual fund sector, regulatory institutions such as the SEC have introduced new rules that allow mutual funds to practice swing pricing to alleviate the risk of investor runs. Studies in Europe where swing pricing has been adopted for many years suggest its potential power to reduce fragility (See, e.g., Jin, Kacperczyk, Kahraman, and Suntheim (2020)). It would be interesting to examine how the regulatory changes in the U.S. influence mutual fund investor behavior and the fragility in illiquid asset prices.

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Appendix A Variable Definition

Variable Name	Definition
Fragility_Amihud	Bond-level fragility measure defined in Equation (2.1) and Equation (2.2)
Fragility_IRC	Bond-level fragility measure defined in Equation(2.1) and Equation (2.2)
Fragility_Spread	Bond-level fragility measure defined in Equation (2.1) and Equation (2.2)
Amihud (% per thousand $)	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 Round-trip Costs (IRC) calculated following Dick-Nielsen, Feldhütter, and Lando (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, Hvidkjaer, and Swaminathan (2005): $$r_t = \frac{(P_t + AI_t) + C_t - (P_{t-1} + AI_{t-1})}{P_{t-1} + AI_{t-1}}, \quad (A.1)$$ 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 percent.
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.
MF_Ownership	Mutual funds' holding share of a certain bond, in decimal with range of 0-1,winsorized at the top and bottom 1% level.

Sell_Pressure	We follow Coval and Stafford (2007) to construct bond-level selling pressure measure, based on realized mutual fund trades conditional on fund flows: $$Sell\ Pressure_{i,t} = \frac{\sum_{j=1}^{J}(Sell\ Amt_{j,i,t}\vert Flow_{j,t} < 25^{th}\ Pctl - Buy\ Amt_{j,i,t}\vert Flow_{j,t} > 75^{th}\ Pctl)}{Amount\ Outstanding_{i,t}},$$ 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.
Liquid_Holding	We define the bond-level mutual fund liquid holding measure as: $$Liquid\ Holding_{i,t} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Liquid\ Asset_{j,t}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}},$$ 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 $Fund\ Liquid\ Asset_{j,t}$ is the share of liquid asset holdings (cash and government securities) relative to fund j's total net assets in quarter t. To mitigate the effects of misreporting in CRSP, we follow prior literature and restrict funds' cash holding to the range 0-0.2 (i.e., replacing cash holding with 0.2 when it is over that upper limit and setting cash holding to zero when it is negative. This measure is winsorized at top and bottom 5% level.)
Corp_Holding	We define the bond-level mutual fund corporate bond holding measure as: $$Corp\ Holding_{i,t} = \frac{\sum_{j=1}^{J} Holding\ Amount_{j,i,t} \times Fund\ Corp\ Asset_{j,t}}{\sum_{j=1}^{J} Holding\ Amount_{j,i,t}},$$ 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 $Fund\ Corp\ Asset_{j,t}$ is the share of corporate bond asset holdings (among all fixed-income assets) for fund j in quarter t. This measure is winsorized at top and bottom 1% level.
Yield_Spread	The difference between the corporate bond yield and the Treasury bond yield of the same maturity, in percent. Yield spread is winsorized at top and bottom 1% level.
VIX	Chicago Board Options Exchange's CBOE Volatility Index, a measure of the stock market's expectation of volatility based on S&P 500 index options. This daily measure is calculated to be its average within a quarter.
FTS	Flight-to-Safety (FTS) is a daily dummy measure using equity and bond returns and a model averaging approach, defined and shared by Baele, Bekaert, Inghelbrecht, and Wei (2020), with 1 indicating a "flight-to-safety" day. This measure is calculated to be its average within a quarter.
Recession	Probability of recession is the Smoothed U.S. Recession Probabilities retrieved from FRED (Federal Reserve Bank of St. Louis), at monthly frequency and in percent. It is developed by Chauvet (1998) and incorporates non-farm payroll employment, the index of industrial production, real personal income, and real manufacturing and trade sales. This measure is calculated to be its average within a quarter.

CFNAI	The Chicago Fed National Activity Index (CFNAI) is a monthly index designed to gauge overall economic activity. The CFNAI is a weighted average of 85 existing monthly indicators of national economic activity, constructed to have an average value of zero and a standard deviation of one. A positive index reading corresponds to growth above trend and a negative index reading corresponds to growth below trend. This measure is calculated to be its average within a quarter.
LiquidityBeta	Bonds' liquidity beta is estimated using rolling window regression based on weekly observations over the past year. We first winsorise the all liquidity measures (Amihud, IRC, and Spread) at the top 1% level. We then calculate the average liquidity across all bonds as proxies for systematic liquidity. We regress individual bond weekly liquidity on systematic liquidity and define the estimated coefficient as LiquidityBeta. A higher LiquidityBeta means higher liquidity commonality for the bond. We require at least 6 observations to run a regression.

Figure 1: **Corporate Bond Returns and Yield Spreads during the Covid-19 Crisis**

This figure shows the dynamics of corporate bond returns and yield spreads during the Covid-19 Crisis in March 2020, with the Federal Reserve announcing SMCCF on March 23. Bonds are sorted into terciles based on their end-of-2019 fragility measures, which are calculated based on the illiquidity levels of the bonds' mutual fund holders. Panel A shows the average weekly returns (not annualized, in decimal), weighted by amount outstanding. Panel B shows the average weekly change in yield spreads, weighted by amount outstanding.

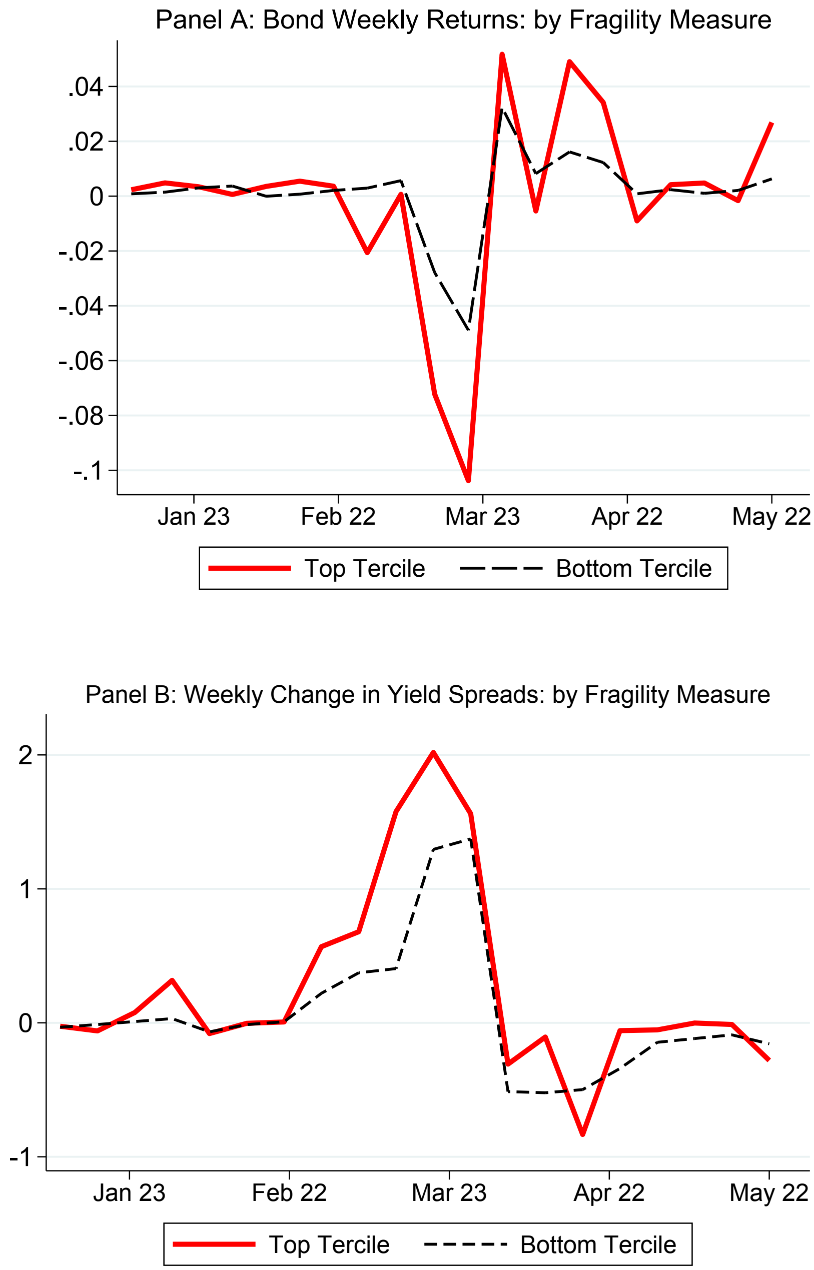

Figure 2: **Mutual Fund Holdings of Corporate Bonds**

This figure shows the total outstanding amount of U.S. corporate bonds (in trillion dollars) and the share held by eMAXX bond mutual funds over the 2006-2019 sample period. The total outstanding amount of U.S. corporate bonds are obtained from the website of The Securities Industry and Financial Markets Association (SIFMA).

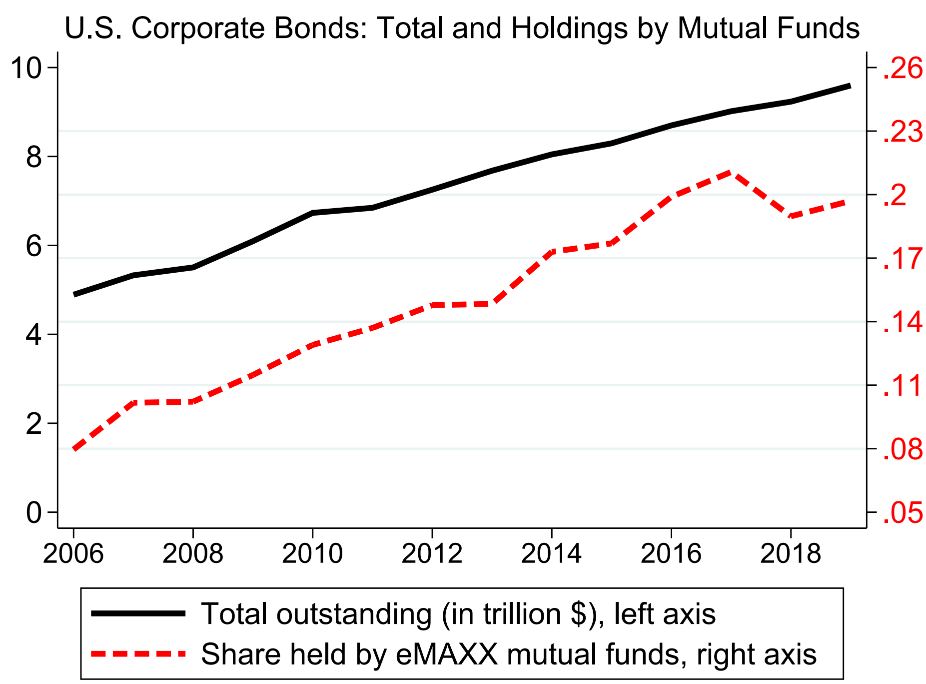

Table 1: **Summary Statistics**

This table provides summary statistics for the variables used in our sample of January 2006 to March 2020. We focus on corporate bond mutual funds and 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. For the the underlying corporate bonds held by mutual funds, we exclude 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. The variables' definitions are provided in Appendix A.

Panel A: Distribution of main variables

Variable	**N**	**Mean**	**S.D.**	**P25**	**Median**	**P75**
Fragility_Amihud (% per $K)	116315	0.05	0.03	0.03	0.04	0.06
Fragility_IRC (%)	116315	0.78	0.28	0.60	0.74	0.92
Fragility_Spread (%)	116315	0.91	0.54	0.58	0.77	1.07
Amihud (% per $K)	116315	0.06	0.09	0.01	0.03	0.07
IRC (%)	116315	0.90	0.75	0.34	0.68	1.24
Spread (%)	116315	1.16	1.15	0.41	0.77	1.51
Turnover(%)	116315	15.87	20.65	4.34	10.19	20.16
Return(annualized)	116315	0.08	0.30	0.00	0.06	0.14
Return_SD (annualized)	115166	0.10	0.11	0.04	0.07	0.12
Rating	116315	9.06	3.64	6.33	8.50	11.33
Size (in thousands)	116315	569769	550507	250000	400000	650000
Maturity (in months)	116315	103	106	37	69	114
Coupon (%)	116315	5.83	1.94	4.70	5.90	7.13
Stock_Vol	116315	0.02	0.01	0.01	0.02	0.02
MF_Ownership	116315	0.13	0.12	0.04	0.10	0.20
Sell_Pressure	113326	-0.0011	0.0089	-0.0019	0.0000	0.0002
Liquid_Holding	115504	0.16	0.09	0.08	0.15	0.22
Corp_Holding	116315	0.65	0.20	0.50	0.63	0.83
Yield_Spread (%)	116264	2.70	4.01	0.90	1.65	3.06
VIX	116315	18.51	7.94	13.73	16.19	20.49
Recession (%)	116315	8.55	25.95	0.05	0.11	0.35
FTS	116315	0.03	0.07	0.00	0.00	0.00
CFNAI	116315	-0.17	0.53	-0.16	-0.04	0.09
LiquidityBeta_Amihud	104619	0.71	4.97	-0.46	0.27	1.57
LiquidityBeta_IRC	112341	1.06	4.73	-0.85	0.72	2.72
LiquidityBeta_Spread	109280	0.94	3.08	-0.13	0.66	1.83

Panel B: Correlations

	Fragility_Amihud	Fragility_IRC	Fragility_Spread	Amihud	IRC	Spread
Fragility_Amihud	1.00					
Fragility_IRC	0.84	1.00				
Fragility_Spread	0.91	0.89	1.00			
Amihud	0.36	0.32	0.32	1.00		
IRC	0.41	0.52	0.42	0.35	1.00	
Spread	0.55	0.57	0.59	0.58	0.62	1.00

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

This table reports regression results of Model (3.1), over the sample period of January 2006 to March 2020. The dependent variable is the standard deviation of corporate bonds' weekly returns measured in quarter $t+1$ (annualized). 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	0.3831***			0.2029*		
	(4.79)			(1.79)		
Fragility_IRC		0.0431***			0.0251***	
		(6.73)			(3.57)	
Fragility_Spread			0.0204***			0.0170**
			(4.14)			(2.08)
Amihud	0.1206***			0.0792***		
	(11.40)			(9.70)		
IRC		0.0169***			0.0078***	
		(8.54)			(6.66)	
Spread			0.0234***			0.0164***
			(15.06)			(13.33)
log(Turnover)	-0.0067***	-0.0081***	-0.0046***	-0.0049***	-0.0059***	-0.0035***
	(-6.79)	(-8.78)	(-5.39)	(-5.01)	(-5.83)	(-3.72)
Rating	0.0053***	0.0050***	0.0042***	0.0096***	0.0093***	0.0083***
	(5.42)	(5.15)	(4.51)	(5.41)	(5.37)	(5.17)
log(Size)	-0.0111***	-0.0113***	-0.0083***	-0.0165***	-0.0183***	-0.0135***
	(-7.71)	(-9.17)	(-5.40)	(-4.57)	(-5.16)	(-4.34)
Return	-0.0374**	-0.0335***	-0.0371***	-0.0404***	-0.0369***	-0.0405***
	(-2.60)	(-2.77)	(-2.84)	(-3.37)	(-3.54)	(-3.67)
Coupon	-0.0010	-0.0002	-0.0004			
	(-1.28)	(-0.22)	(-0.54)			
log(Maturity)	0.0394***	0.0334***	0.0322***	0.0239***	0.0226***	0.0208***
	(14.04)	(12.60)	(11.35)	(4.33)	(4.14)	(3.76)
Stock_Vol	3.0495***	3.0808***	2.5665***	2.5162***	2.5545***	2.2508***
	(11.64)	(11.61)	(10.88)	(11.96)	(11.84)	(10.94)
MF_Ownership	-0.0933***	-0.0882***	-0.0714***	-0.0928***	-0.0928***	-0.0826***
	(-9.71)	(-9.49)	(-9.28)	(-6.37)	(-6.37)	(-6.37)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.554	0.557	0.577	0.648	0.647	0.657
N of obs.	122212	125435	120887	122021	125263	120699

Table 3: **Fragility and Mutual Fund Selling Pressure**

This table reports regression results of Model (3.3), estimated over the sample period of January 2006 to December 2019. The dependent variable is bond's selling pressure from mutual funds, measured in quarter $t+1$, and is defined according to equation (3.2). The independent variables are measured as of quarter t and are 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 selling pressure in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.0148**			0.0320***		
	(2.35)			(5.16)		
Fragility_IRC		0.0006			0.0015***	
		(1.43)			(3.49)	
Fragility_Spread			0.0012***			0.0022***
			(2.76)			(5.19)
Amihud	0.0008**			0.0011***		
	(2.36)			(2.99)		
IRC		0.0001*			0.0001*	
		(1.88)			(1.84)	
Spread			0.0001			0.0001*
			(1.48)			(1.90)
log(Turnover)	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000	-0.0000
	(-0.31)	(-0.97)	(-0.15)	(-0.29)	(-0.48)	(-0.05)
Rating	-0.0000	-0.0000	-0.0000	-0.0001	-0.0001	-0.0001*
	(-0.47)	(-0.44)	(-1.01)	(-1.38)	(-0.85)	(-1.72)
log(Size)	-0.0004***	-0.0004***	-0.0004***	-0.0012***	-0.0011***	-0.0012***
	(-4.19)	(-4.00)	(-3.51)	(-3.47)	(-3.94)	(-3.44)
Return	-0.0000	-0.0000	-0.0000	0.0001	0.0000	0.0000
	(-0.13)	(-0.12)	(-0.14)	(0.30)	(0.22)	(0.30)
Coupon	0.0003***	0.0003***	0.0003***			
	(6.81)	(7.05)	(6.84)			
log(Maturity)	-0.0009***	-0.0009***	-0.0010***	-0.0041***	-0.0040***	-0.0042***
	(-9.16)	(-9.92)	(-8.95)	(-12.64)	(-12.70)	(-12.81)
Stock_Vol	-0.0139*	-0.0115	-0.0164**	-0.0181*	-0.0180*	-0.0217**
	(-1.83)	(-1.47)	(-2.08)	(-1.87)	(-1.83)	(-2.19)
MF_Ownership	0.0072***	0.0070***	0.0071***	0.0229***	0.0226***	0.0232***
	(6.81)	(6.67)	(6.82)	(13.49)	(13.44)	(13.31)
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.050	0.047	0.050	0.098	0.096	0.097
N of obs.	125093	131095	124631	124763	130791	124258

Table 4: **Mutual Fund Selling Pressure and Bond Return Reversal**

This table reports regression results of bond abnormal returns in quarter t (Column (1)) and $t+1$ (Columns (2)-(4)) on bond selling pressure and other characteristics measured in quarter t, as described in Model (3.5), from January 2006 to March 2020. $m+1$ 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). The independent variables are 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: abnormal returns				
	(1)	(2)	(3)	(4)
	t	$m+1$	$m+2$	$m+3$
Sell_Pressure	-0.2840**	-0.1269	0.4262*	0.3824*
	(-2.11)	(-0.65)	(1.85)	(1.85)
log(Turnover)	0.0047***	-0.0003	-0.0006	0.0027
	(2.70)	(-0.20)	(-0.16)	(1.05)
Rating	0.0063	0.0023	0.0037	0.0178**
	(1.57)	(0.43)	(0.73)	(2.19)
log(Size)	-0.0084	0.0232*	-0.0035	-0.0118
	(-0.98)	(1.93)	(-0.20)	(-0.58)
log(Maturity)	0.0130***	0.0182***	0.0098*	0.0013
	(3.84)	(3.87)	(1.72)	(0.14)
Stock_Vol	-1.6254	4.0219***	2.5858	1.2931
	(-1.05)	(3.23)	(1.35)	(1.06)
MF_Ownership	-0.0070	-0.0254	0.0050	-0.0202
	(-0.27)	(-0.64)	(0.10)	(-0.42)
Quarter FE	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes
Adjusted R^2	0.023	0.020	0.026	0.026
N of obs.	124380	126842	124071	123219

Table 5: **Fragility and Bond Returns during the Covid-19 Crisis**

This table reports regression results of Model (4.1). The dependent variable is weekly corporate bond returns (in decimal, not annualized). The sample period spans from the start of 2020 to Mar 21, 2020. For independent variables, fragility/illiquidity measures are as of 2019:Q4. The fragility measures are defined in Equation(2.1) and Equation (2.2). Controls include log(Turnover), Rating, log(Size), Coupon, log(Maturity), and MF_Ownership, as of the end of 2019, and are defined in Appendix A. *Crisis* is a dummy that equals one for the four weeks before the announcement of SMCCF (i.e., the last week in February and the first three weeks in March). Standard errors are clustered at the bond levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Dependent variable: bond weekly return					
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.3704***			0.3826***		
	(7.45)			(7.63)		
Fragility_Amihud × Crisis	-1.0857***			-1.0887***		
	(-6.85)			(-7.29)		
Amihud	-0.0166***			-0.0149***		
	(-3.31)			(-2.99)		
Amihud × Crisis	-0.0555***			-0.0611***		
	(-3.76)			(-4.17)		
Fragility_IRC		0.0372***			0.0381***	
		(7.72)			(7.91)	
Fragility_IRC × Crisis		-0.1044***			-0.1045***	
		(-9.26)			(-9.20)	
IRC		0.0016**			0.0018***	
		(2.32)			(2.65)	
IRC × Crisis		-0.0087***			-0.0099***	
		(-4.21)			(-4.71)	
Fragility_Spread			0.0282***			0.0284***
			(6.19)			(6.24)
Fragility_Spread × Crisis			-0.0775***			-0.0763***
			(-6.72)			(-6.73)
Spread			-0.0004			-0.0003
			(-0.59)			(-0.41)
Spread × Crisis			-0.0098***			-0.0103***
			(-6.31)			(-6.68)
Crisis	-0.0178***	0.0089**	-0.0042			
	(-7.93)	(2.28)	(-1.18)			
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.218	0.223	0.238	0.490	0.507	0.509
N of obs	37670	29949	37071	37670	29949	37071

Table 6: **Fragility and Bond Returns around the SMCCF Announcement**

This table reports regression results of Model (4.2). The dependent variable is weekly corporate bond returns (in decimal, not annualized). The sample period includes two weeks before the SMCCF announcement on Mar 23, 2020, and two weeks after the announcement. For independent variables, fragility/illiquidity measures are as of 2019:Q4. The fragility measures are defined in Equation(2.1) and Equation (2.2). Controls include log(Turnover), Rating, log(Size), Coupon, log(Maturity), and MF_Ownership, as of the end of 2019, and are defined in Appendix A. $SMCCF$ is a dummy that equals one for the two weeks after the announcement of SMCCF. Standard errors are clustered at the bond levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: bond weekly return						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	-0.8990***			-0.9107***		
	(-4.84)			(-5.03)		
Fragility_Amihud × SMCCF	1.6974***			1.7146***		
	(4.96)			(5.03)		
Amihud	-0.0420**			-0.0427**		
	(-2.06)			(-2.13)		
Amihud × SMCCF	0.0311			0.0294		
	(1.08)			(1.03)		
Fragility_IRC		-0.0682***			-0.0688***	
		(-4.20)			(-4.23)	
Fragility_IRC × SMCCF		0.1466***			0.1474***	
		(6.33)			(6.37)	
IRC		-0.0086**			-0.0086**	
		(-2.41)			(-2.43)	
IRC × SMCCF		0.0115**			0.0115**	
		(2.27)			(2.26)	
Fragility_Spread			-0.0496***			-0.0503***
			(-3.55)			(-3.59)
Fragility_Spread × SMCCF			0.1114***			0.1115***
			(5.02)			(5.02)
Spread			-0.0116***			-0.0114***
			(-5.06)			(-5.00)
Spread × SMCCF			0.0115***			0.0114***
			(3.61)			(3.55)
SMCCF	0.0610***	0.0295***	0.0439***			
	(12.51)	(3.71)	(6.49)			
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.348	0.362	0.362	0.378	0.390	0.392
N of obs	13217	10551	13001	13217	10551	13001

Table 7: **Fragility and Bond Return Volatility at Times of Financial Market Stress**

This table reports the results of regressing bond volatility on lagged fragility measure and the interaction of fragility with the financial market conditions. The sample period is January 2006 to March 2020. The dependent variables for both panels are the standard deviation of corporate bond returns measured in quarter $t+1$. Controls include bond illiquidity measures (Amihud, IRC, or Spread), the interaction term between bond illiquidity measures and market indicators, log(Turnover), Rating, log(Size), Coupon (for the first three columns only), log(Maturity), Stock_Vol, and MF_ownership, measured as of quarter t (except for market indicators) and defined in Appendix A. Flight-to-Safety is a daily dummy measure defined and shared by Baele, Bekaert, Inghelbrecht, and Wei (2020), with 1 indicating a "flight-to-safety" day. VIX and Flight-to-Safety (FTS) measures are calculated to be their daily averages in quarter $t+1$. 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: Interacting VIX						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.3440***			0.2671*		
	(3.03)			(1.97)		
Fragility_IRC		-0.0167			-0.0371**	
		(-1.15)			(-2.42)	
Fragility_Spread			-0.0037			0.0031
			(-0.38)			(0.26)
Fragility_Amihud × VIX	0.0016			-0.0031		
	(0.39)			(-0.73)		
Fragility_IRC × VIX		0.0025***			0.0025***	
		(3.84)			(3.16)	
Fragility_Spread × VIX			0.0010***			0.0004
			(3.37)			(1.51)
Controls & Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.555	0.568	0.579	0.649	0.656	0.661
N of Obs.	122212	125435	120887	122021	125263	120699

Panel B: Interacting flight-to-safety (FTS) measure						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.3464***			0.1609		
	(4.13)			(1.37)		
Fragility_IRC		0.0421***			0.0239***	
		(5.82)			(3.15)	
Fragility_Spread			0.0184***			0.0148*
			(3.80)			(1.84)
Fragility_Amihud × FTS	1.1778*			1.4289**		
	(1.72)			(2.47)		
Fragility_IRC × FTS		0.0201			0.0254	
		(0.49)			(0.59)	
Fragility_Spread × FTS			0.0695**			0.0876***
			(2.21)			(2.78)
Controls & Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.554	0.557	0.577	0.648	0.647	0.657
N of Obs.	122212	125435	120887	122021	125263	120699

Table 8: **Fragility and Bond Return Volatility during Economic Downturns**

This table reports the results of regressing bond volatility on lagged fragility measure and the interaction of fragility with the macroeconomic conditions. The sample period is January 2006 to March 2020. The dependent variables for both panels are the standard deviation of corporate bond returns measured in quarter $t+1$. Controls include bond illiquidity measures (Amihud, IRC, or Spread), the interaction term between bond illiquidity measures and macro indicators, log(Turnover), Rating, log(Size), Coupon (for the first three columns only), log(Maturity), Stock_Vol, and MF_ownership, measured as of quarter t (except for macro indicators) and defined in Appendix A. Probability of recession is the Smoothed U.S. Recession Probabilities retrieved from FRED, Federal Reserve Bank of St. Louis. The Chicago Fed National Activity Index (CFNAI) is a monthly index designed to gauge overall economic activity, with a positive index reading corresponding to growth above trend. Probability of recession and CFNAI measures are calculated to be their averages in quarter $t+1$. 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: Interacting probability of recession

	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.3784***			0.2157*		
	(4.22)			(1.78)		
Fragility_IRC		0.0285***			0.0076	
		(3.31)			(0.65)	
Fragility_Spread			0.0137*			0.0122
			(1.74)			(1.07)
Fragility_Amihud × Recession	0.0001			-0.0010		
	(0.08)			(-0.69)		
Fragility_IRC × Recession		0.0006***			0.0006***	
		(3.13)			(3.14)	
Fragility_Spread × Recession			0.0002***			0.0001
			(2.73)			(0.96)
Controls & Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.555	0.565	0.579	0.650	0.654	0.660
N of Obs.	122212	125435	120887	122021	125263	120699

Panel B: Interacting Chicago Fed National Activity Index (CFNAI)

	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.3835***			0.2187*		
	(4.51)			(1.90)		
Fragility_IRC		0.0262***			0.0048	
		(2.95)			(0.40)	
Fragility_Spread			0.0134*			0.0109
			(1.80)			(1.02)
Fragility_Amihud × CFNAI	0.0059			0.0535		
	(0.08)			(0.82)		
Fragility_IRC × CFNAI		-0.0361***			-0.0358***	
		(-4.36)			(-4.03)	
Fragility_Spread × CFNAI			-0.0122***			-0.0055
			(-2.95)			(-1.35)
Controls & Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.555	0.567	0.580	0.650	0.656	0.661
N of Obs.	122212	125435	120887	122021	125263	120699

Table 9: **Exploring the Asset pricing Implication: Fragility and Average Future Bond Returns**

The table reports the regression of abnormal bond return on the lagged fragility measure, over the sample period of January 2006 to March 2020. The dependent variable is the abnormal bond returns in quarter $t+1$ (relative to the mean return of bonds with similar ratings and time-to-maturity during the same period). The fragility measures are defined in Equation (2.1) and Equation (2.2), and are measured as of quarter t. Amihud, IRC, and Spread are bonds' own illiquidity in quarter t. AbReturn is abnormal bond return in quarter t. Return_SD is standard deviation of annualized weekly bond returns calculated over quarter t. Other controls include log(Turnover), Rating, log(Size), Coupon (for the first three columns only), log(Maturity), Stock_Vol, MF_ownership, as of quarter t and are 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: abnormal bond returns in quarter $t+1$						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.0266			0.1228		
	(0.16)			(0.70)		
Fragility_IRC		0.0211**			0.0540***	
		(2.34)			(3.94)	
Fragility_Spread			0.0114			0.0232**
			(1.20)			(2.19)
Amihud	-0.0007			0.0236*		
	(-0.04)			(1.67)		
IRC		-0.0023			0.0039**	
		(-1.04)			(2.06)	
Spread			0.0016			0.0088*
			(0.35)			(1.89)
AbReturn	-0.0291	-0.0327	-0.0265	-0.1090**	-0.1123**	-0.1061**
	(-0.51)	(-0.57)	(-0.47)	(-2.09)	(-2.16)	(-2.06)
Return_SD	0.2362**	0.2256**	0.2280**	0.3574***	0.3432***	0.3377***
	(2.21)	(2.19)	(2.40)	(3.21)	(3.11)	(3.32)
Controls & Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.016	0.016	0.017	0.061	0.062	0.063
N of Obs.	111212	112634	109693	110882	112325	109375

Table 10: **Exploring Asset Pricing Implication: Fragility and Corporate Bond Yield Spreads**

The table reports the regression of bond yield spread on the contemporaneous fragility measure, over the sample period of January 2006 to March 2020. The dependent variable is the change in bond yield spread from the end of quarter $t-1$ to the end of quarter t. ΔFragility_Amihud is the quarterly change in Fragility_Amihud from quarter $t-1$ to t, ΔAmihud is the quarterly change in Amihud measures from quarter $t-1$ to t, and ΔReturn_SD is the quarterly change in bond standard deviation from quarter $t-1$ to t. Ohter controls include contemporaneous quarterly change in log(Turnover), Rating, log(Size), Return, log(Maturity), Stock_Vol, MF_ownership, as 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: change in yield spread from the start to the end of qtr t						
	(1)	(2)	(3)	(4)	(5)	(6)
ΔFragility_Amihud	1.9114			1.3109		
	(0.78)			(0.58)		
ΔFragility_IRC		1.3112**			1.2607**	
		(2.01)			(2.04)	
ΔFragility_Spread			0.6620***			0.5958***
			(2.78)			(3.07)
ΔAmihud	0.5167***			0.4739***		
	(4.29)			(4.07)		
ΔIRC		0.0710***			0.0591***	
		(3.54)			(3.19)	
ΔSpread			0.1992***			0.1803***
			(5.39)			(5.11)
ΔReturn_SD	6.2584***	5.9073***	6.1227***	5.9392***	5.5966***	5.8769***
	(7.09)	(7.42)	(6.76)	(6.90)	(7.36)	(6.64)
ΔControls & Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.354	0.345	0.361	0.350	0.342	0.357
N of Obs.	109597	112526	106933	109088	112035	106424

Table 11: **Liquidity Commonality?–Controlling for Liquidity Beta**

This table reports the results of regressing bond volatility on lagged fragility measure while controlling for lagged liquidity risk. The sample period is January 2006 to March 2020. The dependent variable is the standard deviation of corporate bond returns measured in quarter $t+1$. Fragility measures, illiquidity measures, and liquidity beta are measured in quarter t. Controls include log(Turnover), Rating, log(Size), Coupon (for the first three columns only), log(Maturity), Stock_Vol, and MF_ownership, 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	0.3834***			0.2071*		
	(4.32)			(1.71)		
Fragility_IRC		0.0432***			0.0249***	
		(6.41)			(3.30)	
Fragility_Spread			0.0143**			0.0118
			(2.45)			(1.29)
Amihud	0.1509***			0.1063***		
	(11.82)			(10.20)		
IRC		0.0190***			0.0088***	
		(8.96)			(6.94)	
Spread			0.0275***			0.0202***
			(15.71)			(13.73)
LiquidityBeta_Amihud	0.0001			0.0001		
	(0.67)			(1.12)		
LiquidityBeta_IRC		0.0002**			0.0001*	
		(2.45)			(1.77)	
LiquidityBeta_Spread			0.0007***			0.0006***
			(2.94)			(2.95)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.566	0.559	0.589	0.660	0.650	0.665
N of obs.	106990	119059	111427	106844	118864	111284

Table 12: **Information Asymmetry?–Fragility and Bond Return Reversal**

This table reports regression results of monthly bond returns in quarter $t+1$ on bond characteristics measured in quarter t, as described in Model (5.3), and estimated over the sample period of January 2006 to March 2020. $m+1$ 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). AbReturn is abnormal bond return in quarter t. Controls include log(Turnover), Rating, log(Size), Coupon, log(Maturity), Stock_Vol, and MF_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.

Dependant variables: bond monthly abnormal returns, 1-3 months ahead									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	$m+1$	$m+2$	$m+3$	$m+1$	$m+2$	$m+3$	$m+1$	$m+2$	$m+3$
AbReturn × Fragility_Amihud	-3.7234***	-3.7726***	-1.9948**						
	(-3.11)	(-3.24)	(-2.05)						
AbReturn × Amihud	-0.1717	-0.0995	-0.1092						
	(-0.92)	(-0.52)	(-0.77)						
Fragility_Amihud	-0.1322	0.1973	-0.0964						
	(-0.56)	(0.76)	(-0.37)						
Amihud	0.0920***	-0.0045	0.0122						
	(2.67)	(-0.12)	(0.31)						
AbReturn × Fragility_IRC				-0.4610***	-0.2680	-0.1974			
				(-3.70)	(-1.51)	(-1.41)			
AbReturn × IRC				-0.0267	-0.0547**	-0.0225			
				(-0.96)	(-2.13)	(-1.18)			
Fragility_IRC				0.0409**	0.0248	0.0246			
				(2.60)	(1.42)	(1.13)			
IRC				-0.0012	0.0001	0.0055			
				(-0.33)	(0.04)	(1.15)			
AbReturn × Fragility_Spread							-0.2056***	-0.1415**	-0.1192**
							(-5.22)	(-2.24)	(-2.59)
AbReturn × Spread							0.0089	-0.0359**	-0.0115
							(0.49)	(-2.14)	(-0.98)
Fragility_Spread							0.0267**	0.0059	0.0208
							(2.06)	(0.47)	(1.05)
Spread							0.0121*	0.0048	0.0044
							(1.87)	(0.49)	(0.62)
AbReturn	0.1101	0.3467***	0.1968	0.3298**	0.4156**	0.2840	0.1270	0.4007***	0.2749**
	(1.08)	(4.27)	(1.62)	(2.32)	(2.52)	(1.42)	(1.21)	(4.06)	(2.12)
Controls & Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.028	0.014	0.009	0.031	0.010	0.009	0.030	0.015	0.011
N of Obs.	119339	117742	116986	121651	119750	118980	117826	116242	115490

Table 13: **Fragility Measure, Mutual Fund Portfolios, and Bond Return Volatility**

This table reports the regression results of bond volatility on lagged fragility, and the interaction of fragility with the liquid holdings (Panel A) and the percentage of corporate bond holdings (Panel B). The sample period is January 2006 to March 2020. The dependent variables for both panels are the standard deviation of corporate bond returns measured in quarter $t+1$. Controls include bond illiquidity measures (Amihud, IRC, or Spread), Liquid_Holding for Panel A (Corp_Holding for Panel B), the interaction term between bond illiquidity measure and Liquid_Holding for Panel A (Corp_Holding for Panel B), log(Turnover), Rating, log(Size), Coupon, log(Maturity), Stock_Vol, MF_ownership. All 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.

Panel A. Interacting liquid holdings (cash+government securities)

	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × Liquid_Holding	-1.1167***			-1.4586***		
	(-2.93)			(-3.87)		
Fragility_IRC × Liquid_Holding		0.0024			-0.0978**	
		(0.06)			(-2.36)	
Fragility_Spread × Liquid_Holding			-0.0038			-0.0435**
			(-0.14)			(-2.37)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.558	0.562	0.584	0.651	0.650	0.660
N of Obs.	121329	124461	120019	121143	124294	119830

Panel B. Interacting corporate bond holdings

	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × Corp_Holding	0.7792***			1.0384***		
	(3.57)			(5.23)		
Fragility_IRC × Corp_Holding		0.0257			0.0929***	
		(1.01)			(3.73)	
Fragility_Spread × Corp_Holding			0.0270*			0.0483***
			(1.82)			(4.86)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.558	0.559	0.582	0.650	0.649	0.660
N of Obs.	122212	125435	120887	122021	125263	120699

Internet Appendix

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

Table IA.1: **Fragility and Bond Return Volatility: Robustness**

This table reports regression results of Equation (3.1), over the sample period of January 2006 to March 2020. 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. Controls include bond return volatility in quarter t, log(Turnover), Rating, log(Size), Return, Coupon, log(Maturity), Stock_Vol, and MF_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.

S.D. of bond returns in quarter $t+1$			
	(1)	(2)	(3)
Return_SD	0.5391***	0.5300***	0.5079***
	(19.79)	(19.28)	(19.77)
Fragility_Amihud	0.2002***		
	(3.24)		
Fragility_IRC		0.0179***	
		(3.59)	
Fragility_Spread			0.0094**
			(2.20)
Amihud	0.0438***		
	(6.28)		
IRC		0.0079***	
		(5.56)	
Spread			0.0104***
			(10.63)
Controls	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
Adjusted R^2	0.667	0.666	0.672
N of obs.	120514	122438	118775

Table IA.2: **Fragility and Bond Return Volatility: by Bond Ratings**

This table reports regression results of Equation (3.1), over the sample period of January 2006 to March 2020. The dependent variables for both panels are the standard deviation of corporate bond returns measured in quarter $t+1$. The sample of Panel A includes investment-grade bonds, and the sample of Panel B includes high-yield bonds. Controls include bond illiquidity measures (Amihud, IRC, or Spread), log(Turnover), Rating, log(Size), Return, Coupon, log(Maturity), Stock_Vol, and MF_ownership. All 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.

Sample A: Investment-grade bonds						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.1159*			0.1821***		
	(1.69)			(2.80)		
Fragility_IRC		0.0206**			0.0210**	
		(2.30)			(2.64)	
Fragility_Spread			0.0178**			0.0211***
			(2.58)			(4.49)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.595	0.596	0.603	0.657	0.656	0.661
N of Obs.	85600	88891	84440	85364	88671	84209

Sample B: High-yield bonds						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	0.5377***			0.4231***		
	(6.50)			(4.28)		
Fragility_IRC		0.0943***			0.0644***	
		(8.15)			(4.46)	
Fragility_Spread			0.0299***			0.0349***
			(5.47)			(4.49)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.571	0.581	0.619	0.679	0.679	0.702
N of Obs.	36612	36544	36447	36502	36443	36340

Table IA.3: **Fragility and Mutual Fund Selling Pressure: Robustness**

This table reports regression results of Equation (3.3), estimated over the sample period of January 2006 to December 2019. The dependent variable is selling pressure measured in quarter $t+1$. The independent variables are measured as of quarter t and defined in Appendix A. Controls include lagged value of selling pressure, illiquidity, log(Turnover), Rating, log(Size), Return, Coupon, log(Maturity), Stock_Vol, and MF_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.

Selling Pressure in quarter $t+1$			
	(1)	(2)	(3)
Sell_Pressure	0.1245***	0.1247***	0.1245***
	(9.21)	(9.05)	(9.16)
Fragility_Amihud	0.0139**		
	(2.27)		
Fragility_IRC		0.0005	
		(1.28)	
Fragility_Spread			0.0010**
			(2.53)
Controls	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes
Adjusted R^2	0.063	0.060	0.063
N of obs.	122440	128383	122020

Table IA.4: **Fragility and Additional Selling Pressure Measures**

The table presents results on the predicting power of fragility for additional selling pressure measures over the sample period of January 2006 to December 2019. The dependent variable in Columns (1)-(3) is defined as number of mutual funds holding bond i that experience outflows in quarter $t+1$ minus the number of mutual funds holding bond i that experience inflows in quarter $t+1$. The dependent variable in Columns (4)-(6) is defined as:

$$\frac{\sum_{j=1}^{J}(Sell\ Amt_{j,i,t+1} \times \mathbf{1}(Flow_{j,t+1} < 25^{th}\ Pctl))/\sum_{j=1}^{J}\mathbf{1}(Flow_{j,t+1} < 25^{th}\ Pctl)}{Amount\ Outstanding_{i,t}},$$

where $Sell\ Amt_{j,i,t+1}$ is the par amount of corporate bond i sold by mutual fund j in quarter $t+1$. Thus, it represents the average selling amount (relative to amount outstanding) of bond i in quarter $t+1$ by its holding mutual funds who experience large outflows during the same quarter. The independent variables are measured as of quarter t and defined in Appendix A. Controls include bond illiquidity, log(Turnover), Rating, log(Size), Return, Coupon, log(Maturity), Stock_Vol, and MF_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.

	N of funds with outflow − N of funds with inflows in qtr $t+1$			**Ave. selling amt by funds with large outflows in $t+1$ (scaled by amt outstanding)**		
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	11.0155*			0.0091***		
	(1.93)			(5.24)		
Fragility_IRC		-0.1370			0.0009***	
		(-0.30)			(5.13)	
Fragility_Spread			0.9652**			0.0007***
			(2.22)			(6.14)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Quarter FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond FE	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.552	0.546	0.551	0.162	0.163	0.164
N of Obs.	124784	130816	124282	114370	118230	113776

Table IA.5: **Fragility and Bond Yield Spreads during the Covid-19 Crisis**

The dependent variable is weekly change in corporate bond yield spreads. The sample period spans from the start of 2020 to Mar 21, 2020. For independent variables, fragility/illiquidity measures are as of 2019:Q4. Controls include log(Turnover), Rating, log(Size), Coupon, log(Maturity), and MF_Ownership, as of the end of 2019 and defined in Appendix A. *Crisis* is a dummy that equals one for the four weeks before the announcement of SMCCF (i.e., the last week in February and the first three weeks in March). Standard errors are clustered at the bond levels, with corresponding *t*-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: weekly change in yield spreads						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	-4.4353***			-4.5599***		
	(-3.46)			(-3.56)		
Fragility_Amihud × Crisis	9.2520*			9.5234*		
	(1.86)			(1.94)		
Amihud	-0.1004			-0.1148		
	(-0.61)			(-0.70)		
Amihud × Crisis	1.1710*			1.2967**		
	(1.84)			(2.04)		
Fragility_IRC		-0.8848***			-0.8949***	
		(-6.49)			(-6.52)	
Fragility_IRC × Crisis		2.4291***			2.4253***	
		(7.96)			(7.92)	
IRC		0.0486***			0.0461**	
		(2.63)			(2.51)	
IRC × Crisis		-0.1111			-0.0922	
		(-1.33)			(-1.10)	
Fragility_Spread			-0.6168***			-0.6176***
			(-6.09)			(-6.07)
Fragility_Spread × Crisis			2.2623***			2.2411***
			(6.77)			(6.77)
Spread			0.0239			0.0222
			(1.37)			(1.28)
Spread × Crisis			-0.0285			-0.0164
			(-0.58)			(-0.33)
Crisis	0.6862***	-0.1428	0.1092			
	(9.30)	(-1.36)	(1.08)			
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.138	0.124	0.146	0.187	0.170	0.194
N of obs	34680	27686	34273	34680	27686	34273

Table IA.6: **Fragility and the SMCCF Announcement Effect on Bond Yield Spreads**

The dependent variable is weekly change in corporate bond yield spreads. The sample period includes two weeks before the SMCCF announcement on Mar 23, 2020, and two weeks after the announcement. For independent variables, fragility/illiquidity measures are as of 2019:Q4. Controls include log(Turnover), Rating, log(Size), Coupon, log(Maturity), and MF_Ownership, as of the end of 2019 and defined in Appendix A. *SMCCF* is a dummy that equals one for the two weeks after the announcement of SMCCF. Standard errors are clustered at the bond levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: weekly change in yield spreads						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud	8.1044			7.6742		
	(0.82)			(0.78)		
Fragility_Amihud × SMCCF	-0.7323			-0.7256		
	(-0.05)			(-0.05)		
Amihud	2.2641*			2.2781*		
	(1.89)			(1.90)		
Amihud × SMCCF	-2.6626			-2.6428		
	(-1.58)			(-1.57)		
Fragility_IRC		1.3758**			1.3484**	
		(2.46)			(2.41)	
Fragility_IRC × SMCCF		-3.1603***			-3.1299***	
		(-4.77)			(-4.72)	
IRC		0.0405			0.0395	
		(0.26)			(0.25)	
IRC × SMCCF		0.0957			0.1088	
		(0.54)			(0.61)	
Fragility_Spread			1.8622***			1.8392***
			(3.22)			(3.19)
Fragility_Spread × SMCCF			-2.8243***			-2.8249***
			(-3.90)			(-3.91)
Spread			0.0447			0.0417
			(0.44)			(0.41)
Spread × SMCCF			-0.0909			-0.0910
			(-0.51)			(-0.51)
SMCCF	-0.6469***	0.7338***	0.2601			
	(-3.35)	(3.24)	(1.30)			
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.082	0.078	0.085	0.142	0.139	0.146
N of obs	12258	9781	12110	12258	9781	12110

Table IA.7: **Controlling for Liquidity Beta for the Covid-19 Crisis Analyses**

The dependent variable is weekly corporate bond returns (in decimal, not annualized). The sample period spans from the start of 2020 to Mar 21, 2020, with *Crisis* being a dummy that equals one for the four weeks before the announcement of SMCCF (i.e., the last week in February and the first three weeks in March). For independent variables, fragility/illiquidity/liquidity beta measures are as of 2019:Q4. Controls include fragility measures, illiquidity measures, liquidity beta, crisis dummy, log(Turnover), Rating, log(Size), Coupon, log(Maturity), and MF_Ownership, as of the end of 2019, and are defined in Appendix A. Standard errors are clustered at the bond levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: bond weekly return (before and during crisis)						
	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × Crisis	-0.8762***			-0.9041***		
	(-5.21)			(-5.69)		
Amihud × Crisis	-0.1022***			-0.1070***		
	(-6.05)			(-6.24)		
LiquidityBeta_Amihud × Crisis	-0.0004***			-0.0004***		
	(-3.03)			(-3.29)		
Fragility_IRC × Crisis		-0.1065***			-0.1069***	
		(-9.09)			(-9.03)	
IRC × Crisis		-0.0105***			-0.0117***	
		(-4.97)			(-5.53)	
LiquidityBeta_IRC × Crisis		-0.0004***			-0.0004***	
		(-2.97)			(-3.29)	
Fragility_Spread × Crisis			-0.0679***			-0.0684***
			(-5.15)			(-5.20)
Spread × Crisis			-0.0101***			-0.0106***
			(-5.83)			(-6.04)
LiquidityBeta_Spread × Crisis			-0.0002			-0.0001
			(-0.98)			(-0.83)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.225	0.228	0.237	0.505	0.508	0.521
N of obs	26856	28867	27709	26856	28867	27709

Table IA.8: **Controlling for Liquidity Beta for the Covid-19 SMCCF Analyses**

The dependent variable is weekly corporate bond returns (in decimal, not annualized). The sample period includes two weeks before the SMCCF announcement on Mar 23, 2020, and two weeks after the announcement, with $SMCCF$ being a dummy that equals one for the two weeks after the announcement of SMCCF. For independent variables, fragility/illiquidity/liquidity beta measures are as of 2019:Q4. Controls include fragility measures, illiquidity measures, liquidity beta, SMCCF dummy, log(Turnover), Rating, log(Size), Coupon, log(Maturity), and MF_Ownership, as of the end of 2019, and are defined in Appendix A. Standard errors are clustered at the bond levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Fragility_Amihud × SMCCF	1.4997***			1.5284***		
	(3.86)			(3.90)		
Amihud × SMCCF	0.0346			0.0305		
	(1.03)			(0.90)		
LiquidityBeta_Amihud × SMCCF	0.0008***			0.0008***		
	(2.80)			(2.67)		
Fragility_IRC × SMCCF		0.1527***			0.1535***	
		(6.39)			(6.44)	
IRC × SMCCF		0.0150***			0.0151***	
		(2.89)			(2.90)	
LiquidityBeta_IRC × SMCCF		0.0015***			0.0016***	
		(3.89)			(3.99)	
Fragility_Spread × SMCCF			0.1295***			0.1307***
			(4.26)			(4.27)
Spread × SMCCF			0.0062			0.0059
			(1.62)			(1.51)
LiquidityBeta_Spread × SMCCF			0.0004			0.0004
			(0.95)			(0.89)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Week FE	No	No	No	Yes	Yes	Yes
Adjusted R^2	0.387	0.372	0.391	0.423	0.403	0.427
N of obs	9520	10212	9803	9520	10212	9803