Mutual Fund Fragility, Dealer Liquidity Provisions, and the Pricing of Municipal Bonds*

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Abstract

We study the Covid-19 financial crisis to examine the role dealers play in transmitting potential fragility risks posed by mutual funds to the municipal bond market. Following unprecedented outflows from muni mutual funds, we show that bonds held by these funds trade substantially more and suffer greater price depressions than bonds not in muni funds. Dealer liquidity provision declines more in these bonds, exacerbating their market conditions. In the crisis aftermath, dealers reduce their inventories, liquidity worsens, and yield spreads reflect a fire sale premium in bonds held my mutual funds. These effects are greater for bonds held by mutual funds with more Covid-19 exposure and less liquid portfolios.

Keywords: Municipal bonds, mutual fund fragility, dealer, liquidity, yield spread, Covid-19

JEL classification: G14, G18, G21, G23, G24, G28

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1 Introduction

Fixed income mutual funds perform substantial liquidity transformation. They offer short-term liquidity to investors by allowing redemption of shares on a daily basis. At the same time, many of the fixed income assets that they hold rely on dealer intermediation in trading and thus can be very illiquid. Such liquidity mismatch could create incentives for investors to redeem ahead of others in the face of a negative shock (i.e., a first-mover advantage), amplifying withdrawals and leading to more sales of the underlying illiquid assets.[1] Thus, large outflows from fixed income funds could induce asset fire sales and potentially destabilize markets, especially when markets are already under stress. Such destabilizing effects have generated substantial regulatory concern regarding potential financial stability risks of fixed income mutual funds.[2]

In this paper, we use the Covid-19 crisis to analyze the fragility risks that mutual funds introduce to the municipal bond market (or muni market), with a particular focus on the role that dealers play in transmitting such risks. In the two weeks between March 9 and March 23, 2020, investors redeemed mutual fund shares en masse, leading to an unprecedented 16% outflow from municipal bond mutual funds and extraordinary trading dynamics in the muni market. In the illiquid and highly dealer-reliant muni market, dealers' capability and willingness to absorb redemption-induced bulk sales from mutual funds is critical in times of stress. By linking dealer behavior to the specific outflows of muni mutual funds, we show how dealers' unwillingness to provide liquidity transmitted the instability in mutual funds into instability in the underlying, and how these destabilizing effects persisted even after the normalization of muni fund flows. Indeed, we find that in the aftermath of the muni crisis

[1] Research by Diamond and Dybvig (1983), Chen, Goldstein, and Jiang (2010), and Zeng (2017) develop the theoretical basis for such behavior, which is empirically studied in Goldstein, Jiang, and Ng (2017) and Falato, Goldstein, and Hortaçsu (2020), among others.

[2] See, for example, recent regulatory concerns expressed in the US Treasury Financial Stability Oversight Council (FSOC) report "Update on Review of Asset Management Products and Activities"; and in the SEC report at https://www.sec.gov/spotlight/fixed-income-advisory-committee/etfs-and-bond-funds-subcommittee-report-041519.pdf. Indeed, in October 2015, in an effort to reduce the risk that mutual funds will not be able to meet redemption requests, the SEC adopted a new rule requiring open-end registered funds to establish liquidity risk management programs.

dealers continued to reduce their inventories in bonds held by mutual funds, liquidity worsens for those bonds, and their yield spreads widen, reflecting a "fire sale premium" incorporated in longer-term pricing on muni bonds.

The $4 trillion municipal bond market seems particularly well-suited for a study of market fragility induced by mutual fund fire sales and its link to dealer behavior: the market is very large and characterized by low liquidity, there is a high reliance on dealer intermediation, and there are few means to hedge price movements. While retail investors still dominate the muni market, open-end mutual funds have grown to be the largest institutional investors, holding about 20 percent of outstanding muni bonds. In addition, holding concentrations of muni bonds by mutual funds are substantially higher than that of corporate bonds, suggesting that fire sales by muni funds could generate substantial market impact, affecting a large number of household investors.

A natural concern is how we disentangle the effects of mutual fund fragility risks from the broader economic impacts arising directly from the Covid-19 crisis and the effects of bond-specific characteristics. Certainly, the Covid-19 crisis wreaked havoc on the finances of municipalities, creating both higher risk and uncertainty for municipal bond holders (and issuers). But a unique feature of the muni market helps us to differentiate these effects. In particular, municipal bond funds hold positions in only about 30% of bond issues, with the remaining issues held by other investors. This dichotomization allows us to control for the broader impacts of the crisis on the muni market while extricating the specific effects due to mutual fund redemptions and their aftermath. As we show, the behavior of issues held by mutual funds, while similar to that of issues not held by funds before the crisis, diverges both during and after the crisis. We address concerns that bond characteristics could drive our results by controlling for time-varying impacts of various bond characteristics (including bond size, age, time to maturity, coupon, rating, type, sector, and issuer location). Following the approach of Choi, Hoseinzade, Shin, and Tehranian (2020), we also include issuer-date fixed effects, which essentially allows us to test the effects of mutual fund fragility risks by comparing similar bonds issued by the same issuer and traded over the same period.

Our research provides a number of results, three of which we highlight here. First, we provide some of the first evidence of the impact of mutual fund redemptions on the municipal bond market during the Covid-19 crisis. We show how the municipal bond market experienced extreme stress during the Covid-19 crisis, with trading volume increasing six-fold and tax-adjusted yield spreads soaring from less than 1% in late February, to almost 6% by March 23 (Figure 1). Our results show that the drastic increase in trading volume during the crisis is entirely driven by the trading of bonds held by mutual funds. Moreover, using daily fund flow information, we show that a muni bond experiences more intensive trading and larger price depression when its mutual fund holders suffer larger redemptions. At least in this corner of the fixed income markets, our results support fragility risks arising from mutual fund redemptions.

Second, we demonstrate the critical role that dealers play in transmitting these effects to the underlying market. Amidst the surge in demand for liquidity, we find that dealers pull back from liquidity provision, and shift from buying to selling at the height of the crisis. Indeed, we show that dealers' selling during the crisis increases with bonds' mutual fund ownership. Importantly, although muni market conditions quickly normalized, and muni mutual funds started to attract persistent inflows following multiple Federal Reserve and Congressional actions, dealers did not revert to pre-crisis behavior—their inventories in bonds held by mutual funds continue to decline, while inventories in other bonds quickly revert to their pre-pandemic levels. Such reluctance to intermediate bonds held by mutual funds aggravates the liquidity conditions of such bonds in the post-crisis period (May to July). We find a significant increase in bid-ask spreads for bonds held by mutual funds, with the effects particularly pronounced for the most actively traded issues.

Finally, and unique to our study, we find that fragility risks posed by mutual funds are priced in municipal bond yields in the post-crisis period. We show that a 34-basis-point wedge persists between the yield spreads of bonds held by mutual funds and those that are not. We use a triple-difference approach to study how bonds' exposures to potential run risks influence the effects of mutual fund ownership on municipal bond yield spreads. Our test results show that these effects are more pronounced when the assets of a bond's mutual fund holders are more exposed to the Covid-19 crisis, have longer maturity, or are less liquid.[3]

Our paper makes a number of contributions. First, our paper improves our understanding of the role played by dealers in the functioning of fixed income markets. Many studies analyze dealer behavior in the fixed income markets, and link it to a wide range of factors, including search frictions, funding constraints, trading relationships, and financial regulations.[4] In the muni market, several papers have studied how price transparency, dealer market power, and trading networks affect dealer behavior, and ultimately transaction costs and price discovery (see, for examples, Harris and Piwowar, 2006; Green, Hollifield, and Schürhoff, 2007a; Green, Hollifield, and Schürhoff, 2007b; Green, Li, and Schürhoff, 2010; Schultz, 2012; and Li and Schürhoff, 2019). We contribute to this literature by analyzing how dealers' liquidity provisions are affected by their perceptions of fragility risks posed by mutual funds, and how their pulling back from mutual fund held bonds can affect both liquidity and pricing of these bonds. Although compared to credit risks, liquidity on average might be secondary in determining municipal bond yield spreads (Schwert, 2017), we show that liquidity can play a magnifying role in municipal bond pricing when market is under stress.

Second, existing studies on the fragility risks associated with mutual funds have found mixed results on the importance of such effects. While research on equity markets generally

[3]These factors are consistent with those identified by Falato, Goldstein, and Hortaçsu (2020) as contributing to fragility risks.

[4]Fixed income assets have been traded at over-the-counter (OTC) markets with dealers at their centers. A large number of papers have theoretically studied dealer behavior in the OTC markets. See for example, Andersen, Duffie, and Song (2019), Duffie, Gârleanu, and Pedersen (2005), Hendershott, Li, Livdan, and Schürhoff (2020), Üslü (2019), Yang and Zeng (2020), and Zhu (2012). See Weill (2020) for a recent review of the literature. For empirical studies on dealer behavior in various fixed income markets, including the corporate bond, the Treasury bond, and the agency MBS markets, see Adrian, Boyarchenko, and Shachar (2017); Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018); Bao, O'Hara, and Zhou (2018); Chen, Liu, Sarkar, and Song (2020); Di Maggio, Kermani, and Song (2017); Dick-Nielsen and Rossi (2019); Goldstein and Hotchkiss (2020); He, Nagel, and Song (2020); Macchiavelli and Zhou (2020); and O'Hara and Zhou (2020b), and Schultz (2017).

supports such fragility risk,[5] research on fragility in risky fixed income markets is less clear. Research generally supporting investor redemptions leading to fire sales and price depressions includes Feroli, Kashyap, Schoenholtz, and Shin (2014), Falato, Hortacsu, Li, and Shin (2020), Jiang, Li, and Wang (2020), Ma, Xiao, and Zeng (2020), and Jiang, Li, Sun, and Wang (2021). However, recent research by Choi, Hoseinzade, Shin, and Tehranian (2020), using corporate bond mutual fund data from 2002-2014, argues that controlling for issuer effects yields little evidence of fund redemptions driving fire sale pressures, a result they ascribe to fund liquidity management strategies.

Our research can help reconcile these findings. We find strong evidence of fragility even when controlling for time-varying issuer effects, a result at variance with Choi, Hoseinzade, Shin, and Tehranian (2020). But like those authors, we argue that liquidity is a key feature in whether redemptions transmit pressures to underlying markets. In normal times, fund liquidity management may suffice to insulate redemptions. But our paper shows how in a crisis dealer intermediation (of the lack thereof) can exacerbate illiquidity and transmit fragility posed by mutual funds, a prominent concern emerging after the 2008-2009 financial crisis (Falato, Goldstein, and Hortaçsu, 2020).[6] Further, by analyzing the lasting effects of mutual fund fragility risks after the normalization of fund flows, we are the first to demonstrate that not only the actual occurrence, but also the possibility of large mutual fund outflows, can profoundly change dealer behaviors and carry important implications for the liquidity and the pricing of municipal bonds.

Lastly, our study expands our understanding of the effectiveness of various liquidity and credit facilities that the Federal Reserve launched to combat the impact of the Covid-19

[5] Chen, Goldstein, and Jiang (2010) show that outflows are more sensitive to bad performance for illiquid equity funds. Pástor and Vorsatz (2020) analyze the performance and flows of equity mutual funds during the Covid-19 crisis. See Christoffersen, Musto, and Wermers (2014) for a review on equity mutual fund flows. For runs on money market mutual funds, see McCabe (2010), Kacperczyk and Schnabl (2013), Schmidt, Timmermann, and Wermers (2016), and Li, Li, Macchiavelli, and Zhou (2020).

[6] Falato, Goldstein, and Hortaçsu (2020) note that part of the dramatic growth of assets under management of US investment funds since the financial crisis can be attributed to the increased post-crisis banking regulations, which led to the shift of some activities from banks to other market-based intermediaries, such as investment funds.

pandemic on financial markets. Several recent papers examine liquidity movements in the corporate bond markets (Boyarchenko, Kovner, and Shachar, 2020; Haddad, Moreira, and Muir, 2020; Kargar, Lester, Lindsay, Liu, Weill, and Zúñiga, 2020; and O'Hara and Zhou, 2020a).[7] While it is believed that both the Primary Dealer Credit Facility (PDCF) and the Secondary Market Corporate Credit Facility (SMCCF) are instrumental in stabilizing liquidity conditions in the corporate bond markets, assessing their relative contributions is challenging, given that the SMCCF was announced right after the PDCF started operations. Our analysis of dealer behavior in the absence of a Fed's liquidity backstop in the municipal bond markets (i.e., without a facility similar to the SMCCF for corporate bonds), and its impact on liquidity and municipal bond pricing highlights the significance of the Fed's new role as market maker of last resort.

This paper is organized as follows. The next section gives a brief overview of municipal bond trading and its dynamics during the Covid-19 crisis. Section 3 discusses the data in the paper. Section 4 analyzes the crisis period, examining the impact of mutual fund redemptions on trading volume and yield spreads in the underlying bond market. Section 5 studies dealers' behaviors during and after the crisis. Section 6 examines whether fragility risks are priced in municipal bond yield spreads in the post-crisis period. We also explore sources of mutual fund fragility risk and conduct additional analyses to rule out alternative explanations for our findings. Section 7 is a conclusion.

2 Institutional background

The U.S. municipal bond market plays an important role in financing states and municipalities. The market is highly segmented and characterized by a huge amount of outstanding bond issues (over 1 million by the end of 2019). Secondary market trading in munis is limited, as the market is dominated by investors who tend to buy and hold. When bonds do

[7] For studies on recent disruptions in the Treasury markets, see Duffie (2020), and He, Nagel, and Song (2020).

trade, they rely heavily on dealers for intermediation, with a handful of dealers accounting for the majority of trading. There is growing concern that the increased cost of dealers' balance sheet space caused by post-financial crisis banking regulations could hurt dealer liquidity provision (see Bao, O'Hara, and Zhou, 2018; Bessembinder, Jacobsen, Maxwell, and Venkataraman, 2018). There is also the problem that unlike corporate bonds, municipal bonds are hard to hedge.[8] Muni derivatives markets are small, making it difficult to hedge in any size, and large bid-ask spreads compound the problem. These market characteristics could render the municipal bond market fragile in times of stress, when dealers' ability to intermediate trades and absorb shocks is particularly valuable.

A recent trend in the ownership of municipal bonds adds to these fragility concerns. Unlike other fixed income markets, muni markets have traditionally been dominated by retail investors due to tax exemption benefits of municipal bonds. However, over the past decade, mutual fund ownership of municipal bonds has increased notably, with total holding amounts nearly doubled. According to Financial Accounts of the United States (Z.1), as of the first quarter of 2020, direct ownerships of retail investors make up about 46% of the municipal bond market, while investments from open-end mutual funds comprise 20% of the market.[9] The distinct feature of these municipal mutual funds is that they offer daily redemptions to their investors while investing in generally illiquid municipal bonds. Such substantial liquidity transformation could make municipal mutual funds vulnerable to potential run risks and with it the risk of fire sales and subsequent market repercussions.

The muni market experienced severe strains in March 2020 due to the coronavirus pandemic. Runs on municipal bond mutual funds and the severely destabilized municipal market led the Federal Reserve to intervene with a series of facilities related to the muni market. Specifically, the Federal Reserve started the operation of Primary Dealer Credit Facility

[8]The problem is how to short municipal credit. Futures markets have had a troubled history, and the CDS market is small and very limited. An added complication is that munis are typically tax-exempt and hedging vehicles are not. For discussion see "Hedging Munis: It Ain't Easy" and Wang (2018).

[9]Other institutional investors in the municipal bond market include insurance companies and banks, each holding about 12% of outstanding municipal bonds.

(PDCF) on March 20, allowing primary dealers to pledge municipal bonds as collaterals to obtain loans with maturity up to 90 days. On March 23, the Federal Reserve extended asset eligibility for the Money Market Mutual Fund Liquidity Facility (MMLF) and for the Commercial Paper Funding Facility (CPFF) to include certain short-term municipal securities. On April 9, the Federal Reserve and the U.S. Treasury announced the establishment of the Municipal Liquidity Facility (MLF), which can purchase up to $500 billion newly-issued short-term notes directly from nearly 400 eligible borrowers including states, large U.S. counties and cities, certain multi-state entities, and designated revenue bond issuers. Shortly following Fed interventions, muni market conditions start to improve. Muni yield spreads drop substantially (Figure 1), muni mutual fund outflows cease (Figure 2), and muni trade volume begin to return to its pre-pandemic levels (Figure 3).

3 Data

Our paper combines data from multiple sources. For the period from January 3, 2020 to July 17, 2020, we obtain transaction-level data on secondary market trading between dealers and customers from Municipal Securities Rulemaking Board (MSRB), which reports all transactions made by registered broker-dealers in municipal securities. For each transaction, the MSRB data provide trading date and time, par value traded, price, yield, and the direction of trade.

We supplement the MSRB trading data with municipal bond characteristics information from Mergent Municipal Bond Securities Database, including bond rating, amount outstanding, coupon, issuer name, bond sector, bond type (general-obligation bonds, revenue bonds, etc.), whether exempted from federal or state tax, whether insured, etc. Based on information from Mergent, we group municipal bonds into the following sectors: general, education, health and nursing, housing and development, leisure, public service, transportation, and utility. After merging the MSRB data with municipal bond characteristics, we exclude the following municipal bonds from our sample: those not exempt from federal tax, those issued within three months, those maturing within one year, those with insurance, those with floating coupon rates, and those issued by governments in U.S. insular areas.[10]

Consistent with the illiquidity of the municipal bond markets, although over 1 million municipal bonds are outstanding in 2020, only 207,288 issues traded during our sample period and hence are included in our analysis. For each bond in our sample, we obtain data on its par amount held by each mutual fund at the most recent quarter-end from Thomson Reuters' eMAXX database, which provides security-level holding information of fixed-income mutual funds at a quarterly frequency. As of the end of 2019 (i.e., the last snapshot of fund holdings before the onset of the Covid-19 crisis), there are 893 municipal mutual funds reporting their holdings in eMAXX.[11] Given the large number of municipal bonds, the holdings of municipal bonds by mutual funds are highly segregated. On average, a municipal bond is held by 3 mutual funds, and on average a municipal issuer is financed by 24 mutual funds. Out of the 207,288 bonds trading during our sample period, 53,633 have some mutual fund holders, with the rest being held exclusively by other institutions and retail investors. We use these two segments (bonds held by at least one mutual fund and bonds not held by any mutual funds) in our analysis to differentiate the specific effects of mutual fund fragility.

We also obtain municipal mutual fund daily assets under management (AUMs) and investor flow data from Morningstar and link it to eMAXX data by manually matching fund names. We are able to collect daily flow data for 428 municipal bond funds and most of them are matched with security-level holding information from eMAXX. Finally, we collect federal tax rates and state tax rates for the tax year of 2020, and follow Schwert (2017) in calculating tax-adjusted municipal bond yields.[12]

[10]An insular area is a U.S. territory that is neither one of the 50 states, nor a Federal district. Few bonds in the Mergent FISD database are issued in insular areas.

[11]We include both municipal bond mutual funds and balanced bond funds (that hold at least 25 municipal bonds as of the end of 2019), but exclude municipal money market funds.

[12]Source of state tax rates: https://taxfoundation.org/state-individual-income-tax-rates-and-brackets-for-2020/.

4 Mutual fund runs and the muni markets during the Covid-19 crisis

We start by analyzing the impact of mutual fund runs on the underlying muni markets in the Covid-19 crisis. In particular, we examine trading activities across municipal bonds with different exposures to mutual fund runs at the height of the crisis. Using mutual fund daily flow information, we also provide direct evidence on mutual fund flow induced trading and its price impacts in the muni markets.

4.1 Muni market conditions before and during the crisis

The muni market experienced severe strains in March 2020 due to the coronavirus pandemic. Large redemptions from municipal mutual funds possibly played a central role in triggering and exacerbating the unprecedented selling of municipal securities. Based on Morningstar data, municipal mutual funds suffered 16% investor outflows within the two weeks between March 9 and March 23 (Figure 2).[13] Such redemption pressures were accompanied by excessive selling of municipal bonds, with daily trading volume increasing six-fold within the two-week window, mostly driven by the surge in trading of bonds held by mutual funds (Figure 3).

The spike in trade volume for munis held by mutual funds during the crisis period, however, could potentially be attributed to bond characteristics rather than mutual fund ownerships. For example, short-term bonds are likely to have taken a harder hit in March as rapid spread of the virus raised particular concerns on municipalities' abilities to deal with short-term liquidity pressures and meet their debt obligations in the near future. Also, municipal bonds in certain sectors like transportation and nursing homes are likely under more severe stress. Other bond characteristics, such as ratings and location of municipalities, can also affect trading. If muni investors' decisions to trade certain group of bonds are

[13] Based on the 428 municipal mutual funds in Morningstar with daily flow information.

correlated with the bonds' mutual fund ownerships, the drastic increase in trading activities of bonds held by mutual funds could be attributed to the overall selling pressures in certain types of bonds, rather than the sell-offs of mutual funds per se.

We start by comparing characteristics of municipal bonds held by mutual funds with those of other municipal bonds during normal times. Table 1 provides summary information of these two groups of bonds traded during January and February of 2020 (i.e., prior to the start of the crisis), with bonds held by mutual funds accounting for about 30% of this normal-time bond sample. Some bond characteristics seem to be important considerations for mutual fund investment. For example, mutual funds tend to invest in larger bonds and bonds with higher daily trading volumes. The mean total par amount outstanding and the mean daily trading volume for bonds invested in by mutual funds are $26 million and $312 thousand respectively, substantially larger than those for other bonds, which are only $4.2 million and $141 thousand. In addition, compared to other bonds, those held by mutual funds are rated lower and carry a somewhat higher coupon rate.[14] There is little difference in age between the two groups of municipal bonds, while the mean number of years to maturity is about 10.2 years for mutual fund invested bonds, higher than that for other bonds (8.3 years).

4.2 Mutual fund ownership and bond trading activities

To test formally whether mutual fund ownership, rather than bond characteristics, drives the drastic surge in municipal bond trading volume during the Covid-19 crisis, we use muni trading data (excluding inter-dealer trades) and construct a bond-date sample that includes both the two-week crisis period (from March 9 to March 20) and a pre-crisis period of the

[14] Since a bond can be rated by multiple rating agencies, we assign a composite rating to each bond on each day. If a bond is rated by only one of the three rating agencies, the rating it receives is set to be its composite rating. For a bond rated by two rating agencies, we take the lower of the two ratings as its composite rating. For those rated by all three rating agencies, their composite ratings are determined by the median of the three ratings.

same length (from February 24 to March 6).[15] We estimate the following empirical model:

$$\log(Trading\ Volume_{i,t}) = \alpha + \beta_1 Held\ by\ MF_{i,t} + \beta_2 Crisis_t + \beta_3 Crisis_t \times Held\ by\ MF_{i,t} + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \epsilon_{i,t}, \quad (4.1)$$

where $Trading\ Volume_{i,t}$ refers to total par amount traded in bond i on day t, $Crisis_t$ is a dummy equal to one for the period from March 9 to March 20, and $Held\ by\ MF_{i,t}$ is a dummy equal to one if the bond is held by mutual funds as of the end of 2019. $X_{i,t}$ represents a set of bond characteristics, including number of years since issuance (Age), number of years to maturity ($Year\ to\ Maturity$), coupon rate ($Coupon$), and the logarithm of total par amount outstanding ($\log(Amount\ Outstanding)$). Bond credit ratings are controlled by rating fixed effects (μ_{rating}).[16] Standard errors are clustered at the bond and date levels.

We also take account of additional bond characteristics that could drive potential differential impacts of the pandemic on bond trading activities. Although the whole muni market suffered from the spread of the virus, the crisis likely affected municipal bonds differently along several dimensions. First, sources of repayments for municipal bonds could generate different investor concerns. For example, a revenue bond could be greatly affected if the pandemic causes serious disruptions to the dedicated revenue streams from the specific project or source used to secure the bond. For a general obligation (GO) bond that is backed by the taxing power of governments, the concerns mostly lie in the decline in revenue from taxes and the higher expenditures for healthcare and social services. Second, the impact of the pandemic could vary for bonds in different sectors.[17] For example, essential service sectors such as public service and utilities were generally well insulated from the spread of the virus, whereas sectors like transportation and health care likely took a harder hit.[18]

[15] Our definition of the crisis period is generally consistent with the overall deterioration of the muni market (featured by substantial mutual fund outflows and surging bond yield spreads) and excludes days after the Federal Reserve's interventions related to the municipal market.

[16] Bond ratings are categorized into AAA, AA, A, BBB, and high-yield. Note that high-yield bonds only make up about 0.6% of our sample.

[17] We group municipal bonds into the following sectors: general, education, health & nursing care, housing & development, leisure, public service, transportation, and utility.

[18] Reduced commuter traffic as a result of extensive teleworking and slumped travel demand due to concerns

Finally, municipal issuers in different geographic locations could also be affected differently during the pandemic. While the virus affected all 50 states, some states faced more dire situations.[19] In addition, credit risk implications differ across states due to their different policies on financially distressed municipalities, as shown by Gao, Lee, and Murphy (2019).

To control for the potential differential impact of the pandemic on municipal bonds with the aforementioned characteristics, we further include bond type fixed effects (μ_{type}), bond sector fixed effects (μ_{sector}), and bond state fixed effects (μ_{state}). For bond types, unlimited GO bonds and revenue bonds each account for about one third of our sample, respectively, with the rest belonging to other types of bonds. The largest five sectors in our sample are education (31%), general (30%), utility (16%), transportation (10%), and health care (7%). Our sample includes municipal bond issuers from all 50 states. The top three states with the most actively traded municipal bonds are California (14%), New York (12%), and Texas (10%), together accounting for 36% of bond-day observations in our sample.

If mutual fund ownership drives the drastic surge in municipal bond trading during the Covid-19 crisis, we should expect a positive coefficient of the interaction of $Held\ by\ MF$ and $Crisis$. Indeed, Column (1) in Table 2 shows that compared to other bonds, those held by mutual funds experience an additional 29% increase in trading activities during the crisis period. Interestingly, for bonds not held by mutual funds, trading activities actually decline by 6.6% during the crisis period after controlling for bond characteristics. This finding reinforces the role played by mutual funds in driving the surge in trading volume during the crisis (Figure 3).

In addition, if the drastic increase in trading volume can indeed be attributed to mutual funds' trading activities, we would expect a bond's excessive trading during the crisis period to increase in the levels of its mutual fund ownership. To test this hypothesis, we calculate

about the coronavirus dramatically reduced revenues for municipal bonds in the transportation sector. For the health care sector, increased hospitalization of Covid-19 cases and social distancing likely forced care providers to cut back on elective procedures that usually bring in higher profits.

[19] As of January 15, 2021, New York reports the highest number of deaths while California has the highest number of confirmed cases in the United States.

$MF\ Share$, which is defined as the share of a bond's outstanding amount held by mutual funds at the most recent quarter end (i.e., the end of 2019) and equals zero if the bond is not held by mutual funds. We then replace the dummy $Held\ by\ MF$ with $MF\ Share$ and re-estimate Model (4.1). Consistent with our hypothesis, Column (2) of Table 2 shows that the coefficient of the interaction of $MF\ Share$ and $Crisis$ is positive and highly significant, implying that trading volume increases more in bonds held more by mutual funds during the crisis period. Controlling for general trends in muni market trading by including day fixed effects (μ_t) does not change our results (Column (3)).

One could argue that our results are driven by some unobservable issuer characteristics. It could be that bonds issued by certain municipalities experience more intensive trading than other bonds issued within the same state and belonging to the same sector during the crisis and just happen to be held more by mutual funds. To address this concern, we re-estimate Model (4.1) by controlling for both bond characteristics ($X_{i,t}$) and issuer fixed effects (μ_{issuer}). Column (4) shows that our results change little.

Lastly, to control for potential time-varying impacts of both bond and issuer characteristics on trading activities, we interact bond characteristics $X_{i,t}$ with the $Crisis$ dummy and include them as additional controls. In addition, we include issuer-date fixed effects, which essentially allow us to compare trading activities for bonds issued by the same issuer and traded on the day and test whether those held more by mutual funds are traded more heavily in the crisis. Although controlling for issuer-date fixed effects notably reduces our sample size, Column (5) shows that our results continue to hold. Together, results in Table 2 lend strong support to the hypothesis that the sharp increase in trading activities of municipal bonds during the crisis period can be attributed to bonds with mutual fund holders, likely stemming from mutual funds selling their holdings in response to extraordinary outflows.

4.3 Mutual fund flow-induced trading and price impact

So far, we rely on mutual fund ownership to capture the potential fire sales risks that mutual funds can introduce to that bond. To understand better the potential sell-offs induced by mutual fund redemptions, we directly test the link between mutual fund outflows and muni trading using information on both CUSIP-level holdings and daily fund flows. We then test the price impact of flow induced trading by linking yield spread of munis to recent redemptions to their mutual fund holders.

Specifically, we include only municipal bonds that are held by mutual funds as of the end of 2019 and analyze the impact of mutual fund flows on their trading activities during the crisis period (i.e., from March 9 to March 20, 2020). To capture the impact of mutual fund flows on municipal bond trading, we construct a bond-level mutual fund flow measure, $MF\ Outflow_{i,t}$, which is defined as:

$$MF\ Outflow_{i,t} = \frac{\sum_{k=1}^{K} Holding\ Amount_{i,k} \times Outflow_{k,t-1,t}}{\sum_{k=1}^{K} Holding\ Amount_{i,k}}, \tag{4.2}$$

where $Outflow_{k,t-1,t}$ is fund k's cumulative percentage outflows (adjusted for fund returns) over the most recent two business days (i.e., day $t-1$ and day t), and $Holding\ Amount_{i,k}$ is the dollar amount of municipal bond i held by fund k as of the end of 2019.[20] Therefore, $MF\ Outflow_{i,t}$ represents on average how much outflow bond i's mutual fund holders have suffered recently, weighted by each investing fund's holding amount of that bond. We then estimate the following empirical model:

$$\log(Trading\ Volume_{i,t}) = \alpha + \beta MF\ Outflow_{i,t} + \gamma X_{i,t} + \\ \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \mu_t + \epsilon_{i,t}, \tag{4.3}$$

using the sample that covers only the crisis period. If some of the surge in trading during the crisis is directly attributed to mutual fund selling their bonds to meet redemptions, we should expect volume to increase when the holding funds experience larger outflows.

[20]Our results are qualitatively similar when using outflows over the most recent one or three business days.

Indeed, as Column (1) of Table 3 shows, the coefficient of $MF\ Outflow$ is positive and highly significant, suggesting that mutual fund redemptions drive excessive trading in the municipal market during the Covid-19 crisis. Specifically, a one-percentage-point increase in the outflow of a bond's holding funds is associated with a 26% increase in that bond's trading activities during the crisis. In addition, $MF\ Share$ continues to have a strong positive impact on trading volume when included as an additional explanatory variable, indicating that in addition to redemption-induced liquidation, mutual funds may also engage in preemptive selling of their holdings with the fear for additional outflows during the crisis (Column (2)). Again, controlling for issuer fixed effects (Column (3)) does not change our results. Our conclusion holds even when we include issuer-date fixed effects (Column (4)), suggesting that for bonds issued by the same issuer and traded on the same day, those suffering more mutual fund outflows experience significantly more intensive trading during the crisis.

How does excessive trading in bonds held by mutual funds affect the underlying muni markets? Given the general illiquidity of the muni market, the surge in demand for liquidity from mutual funds facing large redemptions is likely to further exacerbate market conditions and depresses municipal bond prices. To analyze the potential price impact of flow induced trading, we continue to use bonds that are held by mutual funds and focus on the crisis period. We then re-estimate Model (4.3) by using $Yield\ Spread_{i,t}$ as the dependent variable. $Yield\ Spread_{i,t}$ is defined as the yield spread (adjusted for both federal and state taxes, relative to same-maturity treasury bond yield) for bond i on day t, calculated as in Schwert (2017). In additional to all controls used in Model (4.3), we also control for the bond's trading activities.

Table 4 shows that mutual fund flow-induced trading is likely to have pushed yield spreads higher during the crisis period. Column (1) shows that during the crisis, a bond's yield spread widens by 6 basis points for a one-percentage-point increase in the outflow of the bond's mutual fund holders. In addition, yield spreads tend to be higher in bonds held more by mutual funds, suggesting that not only the realized outflows, but also the concerns for future mutual fund outflows could have precipitated trading and thus exerting price impact in the muni markets (Column (2)).[21] Our results are robust to controlling for issuer fixed effects (Column 3)) and issuer-date fixed effect (Column (4)). Together, these findings point to the destabilizing effects of mutual funds flows on the muni market during the Covid-19 crisis.

5 Changes in dealer behavior around the crisis

Integral to the impact of heightened liquidity demand from mutual funds on the underlying muni market is the behavior of dealers. As discussed earlier, the muni market is highly illiquid and relies heavily on dealers for intermediation. Therefore, the degree of the threat posed by mutual fund selloffs to muni market stability largely depends on dealers' liquidity provision. The muni market could withstand large temporary selloffs by mutual funds if dealers step up to absorb these sales. Although a number of papers have studied dealers' overall liquidity provisions in fixed-income markets during a crisis,[22] little is known about how dealers respond to bonds facing potential mutual fund run risks.

5.1 Dealer trading and mutual fund exposures during the crisis

To understand the role dealers play in transmitting mutual fund run risks, we first study dealer trading behavior around the crisis period. Figure 5 shows dealers' aggregate cumulative inventory changes since the beginning of 2020, separately in bonds held by mutual funds and those not. Although dealers occasionally buy more bonds held by mutual funds than by others in January and early February of 2020, their cumulative inventories in these two groups of bonds are at similar levels in late February. Starting about two weeks prior

[21] The pricing implications of the potential run risks posed by mutual funds will be further studied in our analysis on the aftermath of the crisis in Section 6.

[22] See, for examples in the context of corporate bonds, Bao, O'Hara, and Zhou (2018), Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018), Dick-Nielsen and Rossi (2019), Schultz (2017), and O'Hara and Zhou (2020a).

to the beginning of massive mutual fund redemptions on March 9, dealers accumulate more inventories in bonds held by mutual funds than in other bonds, potentially reflecting some mutual funds' efforts to build up their cash reserves in anticipation of potential redemptions. Meanwhile, dealers seem to sell some of the bonds not held by mutual funds to free up their balance sheets to accommodate sales by mutual funds.

When large outflows from mutual funds start on March 9, however, dealers quickly shift to selling bonds which are likely to face usual high selling pressures from mutual funds. During the two-week crisis period, dealers' cumulative inventories in bonds held by mutual funds drop by over 50%. So while muni dealers purchased some bonds sold by mutual funds before the onset of the crisis, they stop absorbing such shocks when mutual funds suffer large redemptions during the crisis. Dealers' drastic reverse of positions when liquidity is needed the most seems likely to exacerbate the fragility risks posed by mutual fund runs when the muni market is under stress.

To empirically test these effects, we measure dealers' daily trading using $Dealer\ Net\ Purchase_{i,t}$, defined as the difference between dealers' aggregate purchases from customers and their aggregate sales to customers in bond i on day t. We then use the sample that covers both the pre-crisis and the crisis periods (i.e., from February 24 to March 20), and estimate the following empirical model:

$$\begin{aligned} Dealer\ Net\ Purchase_{i,t} &= \alpha + \beta_1 Held\ by\ MF_{i,t} + \beta_2 Crisis_t + \beta_3 Held\ by\ MF_{i,t} \times Crisis_t \\ &\quad + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \epsilon_{i,t}, \end{aligned} \tag{5.1}$$

where the explanatory variables are defined as in Model (4.1), and standard errors are clustered at the bond and date levels.

Consistent with the overall patterns observed in Figure 5, Column (1) of Table 5 shows that the coefficient of $Held\ by\ MF$ is positive and significant, in line with dealers accumulating greater inventories in bonds held by mutual funds during the pre-crisis period. More importantly, the interaction of $Held\ by\ MF$ and $Crisis$ is negative, highly significant, and is substantially larger compared with the coefficient of *Held by MF*. Specifically, dealers on average sell more bonds with mutual fund holders during the crisis time (by around $20,000 per bond-day, on net), relative to bonds not held by mutual funds. This result implies that dealers' inventories decline in bonds that are likely facing selling pressures from mutual funds in the crisis period. We obtain consistent results when replacing *Held by MF* with *MF Share* (Column (2)). Our results are robust to controlling for general time trends (Columns (3)), unobservable issuer characteristics (Column (4)), and potential time-varying bond and issuer-specific impacts (Column (5)).

5.2 Dealer behavior change in the aftermath of the crisis

Massive redemptions from muni funds subsided shortly after the Federal Reserve announced a series of measures intended to aid municipalities and ease market conditions. In April, muni fund flows largely normalize, and in May muni funds start to attract consecutive inflows (Figure 2). Interestingly, dealers continue to lower their inventories in municipal bonds held by mutual funds after the stabilization of mutual fund flows (Figure 5). Over our sample period from the start of 2020 to July 17, 2020, dealers' total cumulative inventories in mutual-funds-held bonds decline by over $1 billion on net. This is particularly intriguing, as for bonds not held by mutual funds, dealers shift back to buying shortly after the Fed's interventions in late March, and their inventories in these bonds change little since the beginning of May, staying close to their levels seen at the beginning of 2020.

Post-crisis dealer behavior in the muni market contrasts sharply with that in the corporate bond market which also suffered extraordinary mutual fund outflows at the height of the crisis.[23] O'Hara and Zhou (2020a) find that as in the muni markets, dealers are net sellers in the corporate bond market during the two weeks leading up to the Fed's interventions. However, corporate bond dealers start to increase their inventories immediately after March 23 and by mid-May, their inventories have risen to substantially higher levels than they were

[23]For studies on corporate bond mutual fund outflows during the Covid-19 crisis, see Falato, Goldstein, and Hortaçsu (2020), and Ma, Xiao, and Zeng (2020).

at the beginning of February.

The stark contrast between dealers' behavior in the muni and corporate bond markets potentially reflects different Federal Reserve measures taken in the two markets. In the corporate bond market, the announcement of the SMCCF substantially reduced dealers' concerns on turning around their inventories, thereby increasing their willingness to provide liquidity (O'Hara and Zhou, 2020a). However, there is no comparable facility directly targeting the muni secondary market. In fact, Federal Reserve facilities related to municipal bonds either target the primary market (MLF), or the short-term municipal bond markets (MMLF and CPFF), or a small subset of dealers (PDCF). Without the Federal Reserve essentially acting as market maker of last resort, and facing the perennial problem of limited ways to hedge risk in municipal bonds, it seems likely that dealers kept shrinking their inventory of municipal bonds that bear potential mutual fund fire sale risks.

To formally test this hypothesis, we use a bond-day sample spanning from January 2 to July 17, 2020 (excluding March and April) and estimate the following empirical model:

$$
\begin{aligned}
&Cumu\ Inventory\ Change_{i,t} = \alpha + \beta_1 PostCrisis_t + \beta_2 Held\ by\ MF_{i,t} + \\
&\quad \beta_3 PostCrisis_t \times Held\ by\ MF_{i,t} + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \epsilon_{i,t}, \quad (5.2)
\end{aligned}
$$

where $Cumu\ Inventory\ Change_{i,t}$ refers to the cumulative dealer inventory changes in bond i since the beginning of 2020. $PostCrisis_t$ is a dummy that takes the value one for the period from May 1 to July 17, 2020. $Held\ by\ MF_{i,t}$ is a dummy variable that takes the value of one if bond i is held by mutual funds at the most recent quarter-end. The other variables are defined as in Model (4.1), and standard errors are clustered at the bond and date levels.

We exclude March and April from this regression sample to minimize the direct and immediate impact of mutual fund runs and the following government interventions on the dynamics in the muni market during the post-crisis period. Given that municipal mutual funds experienced persistent inflows since the start of May (as they did in January and February), we see no reason to believe that mutual fund redemptions directly drive the post-crisis dynamics in the muni market. Rather, it is more likely that the salient destabilizing role played by mutual funds during the crisis and lingering credit concerns have reshaped dealers' perceptions of the potential fragility risks posed by municipal mutual funds.

Results in Table 6 support our contention that fear for potential fire sales by mutual funds has greatly affected dealers' willingness to take inventories of bonds bearing such risks. Column (1) shows even after the stabilization of fund flows, dealers' cumulative inventories decline in bonds held by mutual funds, as suggested by the negative and highly significant coefficient of the interaction of *Held by MF* and *PostCrisis*. Specifically, compared to municipal bonds not held by mutual funds, those with mutual fund holders on average suffer an additional $267,000 decrease in dealer inventory over the post-crisis period. We obtain consistent results when replacing the *Held by MF* dummy with *MF Share*, showing that the decline in dealer inventory during the post-crisis period is greater in bonds more heavily held by mutual funds (Column (2)). Our conclusion holds when controlling for the general time trends in dealer inventories (Column (3)), issuer fixed effects (Column (4)), as well as potential time-varying impacts of bond and issuer characteristics (Column (5)).

How does the change in dealer behavior towards mutual-fund-held bonds affect the post-crisis liquidity of the muni market? One key challenge in addressing this question lies in the estimation of reliable bond-level liquidity measures, especially at relatively high frequency (e.g., daily). Given the muni market is an OTC market, quotes are indicative and only provided by dealers when approached by investors. In addition, a significant portion of muni investors tend to buy and hold their investments to maturity. Therefore, secondary market trading activities in munis are usually very limited. Out of the 160,679 municipal bonds in our sample (from January 2 to July 17, 2020, excluding March and April), only 13,599 bonds trade on more than 10 days (i.e., on average one day every week), and 3,347 bonds trade on more than 20 days (i.e., on average two days every week).

To shed light on whether post-crisis liquidity deteriorates more for municipal bonds held by mutual funds, we estimate a size-matched realized bid-ask spread measure. Given the importance of trade size in affect muni prices (Schultz, 2012), we first calculate a bond's volume-weighted average customer buy prices ($Ask_{i,s,t}$) and its volume-weighted average customer sell prices ($Bid_{i,s,t}$) in a given trade size category and on a given day. We then calculate a bond-day-trade size level bid-ask spread by taking the difference between $Ask_{i,s,t}$ and $Bid_{i,s,t}$. This calculation requires at least one buy and one sell in the same trade size category (i.e., within \$10,000 difference in par amount), in the same bond, and on the same day. Finally, we then calculate a bond-day level measure ($Spread_{i,t}$) by taking the average spread across trade size categories, weighted by the trade volume in each size category:

$$Spread_{i,t} = \frac{\sum_s (Ask_{i,s,t} - Bid_{i,s,t}) \times Volume_{i,s,t}}{\sum_s Volume_{i,s,t}}. \quad (5.3)$$

We then re-estimate model (5.2) by replacing $Cumu\ Inventory\ Change_{i,t}$ with $Spread_{i,t}$ using the same sample. We report the regression results in Table 7. It is worth noting that our sample shrinks substantially as we are unable to obtain valid realized spread estimates for the majority of the bond-day pairs. Nevertheless, in this limited sample, we find some evidence that liquidity deteriorates more in bonds held by mutual funds. The coefficients of both $PostCrisis$ and the interaction of $Held\ by\ MF$ and $PostCrisis$ are positive and highly significant, suggesting that bid-ask spread widens in the post-crisis period, more so for bonds held by mutual funds (Column (1)). We obtain consistent results when replacing the $Held\ by\ MF$ dummy with $MF\ Share$ (Column (2)), and our results are robust to controlling for general time trends and issuer specific effects (Column (3)), as well as time-varying effects of bond and issuer characteristics (Column (4)). We also re-estimate the empirical model on subsamples of more frequently traded bonds. We find that municipal bonds held more by mutual funds experience more severe deterioration in post-crisis liquidity when focusing on bonds that trade on more than 10 days (i.e., about one day per week, see Column (5)) or more than 20 days (i.e., about two days per week, see Column (6)).

Together, these findings suggest that potential fragility risks introduced by mutual funds might have changed dealer behaviors and liquidity conditions in the muni market after the

Covid-19 crisis. Such remarkable change could, in turn, carry important pricing implications, which we explore in the next section.

6 Pricing of mutual fund fragility risks in the aftermath of the crisis

In this section, we analyze whether fragility risks posed by mutual funds are priced in muni yield spreads in the post-crisis period. We also investigate several sources of mutual fund fragility risks stemming from funds' portfolio exposures and examine how they affect muni prices. Finally, we study potential reaching for yield by mutual funds during the post crisis period and rule it out as an alternative explanation for our findings.

6.1 Yield spreads and mutual fund fragility risks

All else being equal, bonds bearing greater potential risks of mutual fund fire sales are likely to be shunned by investors, especially when liquidity provision by dealers in these bonds may be scarce when needed the most. Indeed, Figure 4 shows that a wedge persists between the yield spreads of bonds held by mutual funds and those that are not, even after the normalization of mutual fund flows. Specifically, during the post-crisis period from the beginning of May to mid-July, yield spreads for bonds held by mutual funds are on average 33 basis points higher than those for other bonds. In contrast, these bond with mutual fund ownership trade at 6 basis point discount compared to other bonds during the pre-crisis period (i.e., January and February).

To formally test the effects of mutual fund ownerships on post-crisis bond yield spreads, we use the sample that spans the period from January 2 to July 17, 2020, but excludes March and April, and estimate the following panel regression:[24]

[24]Our results are even stronger when we use a longer pre-crisis period (i.e., from the beginning of 2019 to the end of February, 2020). These results are available upon request.

$$Yield\ Spread_{i,t} = \alpha + \beta_1 PostCrisis_t + \beta_2 Held\ by\ MF_{i,t} +$$

$$\beta_3 PostCrisis_t \times Held\ by\ MF_{i,t} + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \epsilon_{i,t}, \quad (6.1)$$

where $Yield\ Spread_{i,t}$ refers to the tax-adjusted yield spread of bond i on day t. All other variables are defined as in Model (5.2). Standard errors are clustered at the bond and date levels.

In line with Figure 4, Column (1) of Table 8 shows that even after controlling for bond characteristics, bonds held by mutual funds experience an additional 34-basis-piont increase in yield spreads. Consistently, the widening in yield spreads during the post-crisis period increases in mutual fund ownership (Column (2)). Our results are robust to controlling for time trends, issuer specific effects, as well as time-varying effects of bond and issuer characteristics (Columns (3)-(5)).

Is the potential mutual fund fragility risk priced across a wide range of munis, or is it limited to certain types of bonds? Relatedly, how does the impact of mutual fund ownership on muni pricing differ across bonds with different characteristics? To address these questions, we sort observations into subsamples based on a bond's credit rating, whether a bond is a GO bond, or the sector of a bond. We then re-estimate the strictest specification in Table 8 for each of the subsamples, with results presented in Table 9. We find that the post-crisis impact of $MF\ Share$ on muni yield spread tends to be stronger in lower rated bonds (i.e., bonds rated A or lower), non-GO bonds, and in sectors hit harder by the Covid-19 pandemic (i.e., health & nursing care, leisure, and transportation). Nevertheless, the coefficient of the interaction of $MF\ Share$ and $PostCrisis$ is positive and highly significant across all subsamples. Thus, the pricing of potential mutual fund fragility risk is not restricted to a small subset of bonds, but is prevalent in the muni market.

6.2 What is the mechanism? Sources of mutual fund fragility and their pricing implications

Our results on the pricing of mutual fund fragility risks are obtained for the post-crisis period, during which muni funds have actually attracted persistent inflows. Yet the on-going nature of the pandemic is certainly consonant with the fear that investors could run again on mutual funds. To investigate the channel through which mutual fund fragility risks affect muni market pricing, we now explore fund-level factors that could drive investor outflows in times of stress and link those latent fragility sources to the pricing of individual bonds. Intuitively, if mutual fund ownership affects muni pricing through the channel of potential run risks in the post-crisis period, we should obtain much stronger results for bonds bearing higher mutual fund run risks.

To this end, we estimate three measures of mutual fund fragility risks identified by Falato, Goldstein, and Hortaçsu (2020) as factors driving fixed-income fund outflows during the Covid-19 crisis. These are fund exposure to sectors/industries most hit by the Covid-19 pandemic, a fund portfolio's average maturity, and the average illiquidity levels of a fund portfolio. We group munis held by mutual funds into subsamples based on their holding funds' aforementioned fragility sources, and test whether the effects of mutual fund holding shares on muni yield spreads during the post-crisis period intensify when a bond's holding funds are more susceptible to investor runs. In this subsample analysis, which essentially uses triple differences, we exclude bonds not held by mutual funds (which, by definition, bear no latent run risks from mutual funds).

To calculate the bond-level fragility risks associated with the bond's investing mutual funds, the first step is to estimate a fund-level latent risk measure based on the fund's holding portfolio. Specifically, for each muni fund j, we calculate the following run risk measure based on its security-level holdings as of the most recent quarter-end:

$$Fund\ Run\ Risk_{j,t}^{Type} = \frac{\sum_i Bond\ Risk_{i,t}^{Type} \times Holding\ Amount_{i,j,t}}{\sum_i Holding\ Amount_{i,j,t}}, \tag{6.2}$$

where $Bond\ Risk_{i,t}^{Type}$ indicates one of the followings: a dummy indicating whether bond i is in the sectors hit hardest by the pandemic (defined as transportation, health & nursing care, and leisure), the remaining time to maturity of bond i, or the illiquidity level of bond i. $Holding\ Amount_{i,j,t}$ represents the par amount of bond i held by fund j. Therefore, $Fund\ Run\ Risk_{j,t}^{Type}$ represents fund j's sector exposure to the Covid-19 crisis, average portfolio maturity, or the overall illiquidity level of its holdings.[25] The second step is to calculate the bond-level fragility measure stemming from the bond's investing mutual funds:

$$Bond\ Fragility_{i,t}^{Type} = \frac{\sum_j Fund\ Run\ Risk_{j,t}^{Type} \times Holding\ Amount_{i,j,t}}{\sum_j Holding\ Amount_{i,j,t}}, \tag{6.3}$$

where $Fund\ Run\ Risk_{j,t}^{Type}$ and $Holding\ Amount_{i,j,t}$ are defined in Equation (6.2). Intuitively, $Bond\ Fragility_{i,t}^{Type}$ represents on average how much run risks bond i's investing mutual funds entail, weighted by each mutual fund's holding amount of bond i. We then use the median of three types of $Bond\ Fragility_{i,t}$ to split our bond-day sample into subgroups.

First, we expect the impact of $MF\ Share$ on the yield spread of a municipal bond will be stronger when its investing funds' portfolios are more exposed to the pandemic. To test this, we estimate the following model for subsamples sorted by $Bond\ Fragility_{i,t}^{Type}$ (with $Type$ defined as sector exposures to the Covid-19 crisis):

$$\begin{aligned} Yield\ Spread_{i,t} = \alpha &+ \beta_1 PostCrisis_t + \beta_2 MF\ Share_{i,t} + \beta_3 PostCrisis_t \times MF\ Share_{i,t} \\ &+ \gamma_1 X_{i,t} + \gamma_2 PostCrisis_t \times X_{i,t} + \mu_{issuer \times date} + \epsilon_{i,t}. \end{aligned} \tag{6.4}$$

Results in Columns (1) and (2) in Table 10 support our hypothesis that the post-crisis effect of $MF\ Share$ on yield spreads gets stronger when a bond's holding funds are more vulnerable. While the coefficient of the interaction of $MF\ share$ and $PostCrisis$ is highly significant in both subsamples, it is significantly larger in the subsample with large Covid-19

[25] Following Falato, Goldstein, and Hortaçsu (2020), we estimate a fund's asset liquidity using the average credit rating of bonds that a fund hold as of the most recent quarter-end. Falato, Goldstein, and Hortaçsu (2020) also use the Roll (1984) measure and the bid-ask spread as two alternative measures to estimate asset liquidity at fund level. However, given the illiquidity of the muni market, we are unable to estimate these measures for the majority of municipal bonds.

exposure, both economically and statistically.

Second, we expect funds holding longer maturity bonds to be more affected by market fluctuations given their higher interest rate risks, and hence more susceptible to greater outflow pressures. To test this conjecture, we re-estimate Model (6.4) for subsamples sorted by $Bond\ Fragility_{i,t}^{Type}$ (with $Type$ defined as maturity risk). Columns (3) and (4) show that the coefficient of the interaction of $MF\ share$ and $PostCrisis$ is substantially larger when bonds' mutual fund holders' portfolio maturities are longer, with the difference significant at the 1% level.

Lastly, the illiquidity of a fund's asset holdings can drive strategic complementarities among its investors when deciding to redeem their shares, as emphasized by Chen, Goldstein, and Jiang (2010) and Goldstein, Jiang, and Ng (2017). The less liquid a fund's assets, the greater liquidity mismatch a fund exhibits, and the larger the incentives for investors to redeem ahead of others. If fund illiquidity exacerbates the tendency of investors to run and amplify fragility, the effects of mutual fund holding shares on muni yield spreads should be stronger when its investing funds hold less liquid assets. We test this hypothesis by re-estimating Model (6.4) for subsamples sorted by $Bond\ Fragility_{i,t}^{Type}$ (with $Type$ defined as illiquidity risk). We again find stronger pricing effects in the subsample with higher mutual fund liquidity risks (proxied by lower portfolio ratings of the bond's mutual fund holders). The coefficient of the interaction of $MF\ share$ and $PostCrisis$ for bonds whose mutual fund investors hold lower rated portfolios is over 4 times larger than that for other bonds, with the difference significant at the 1% level.

Together, these results show that the riskiness of mutual fund holdings carry important implications for municipal bond pricing in the post-crisis period. These results not only reveal the underlying mutual fund fragility sources that drive individual bond pricing, but also point to the sophistication of the muni market in identifying and pricing in these latent fragility factors.

6.3 Is it reaching for yield?

An alternative explanation for our finding that yield spreads are positively associated with $MF\ Share$ in the post-crisis period is that mutual funds have a stronger incentive to reach for yield during the post-crisis period when interest rates moved to near zero levels.[26] In other words, it might be that mutual funds actively initiate or increase their holdings in municipal bonds with higher yields in the post-crisis period, in the face of near zero policy rates. Choi and Kronlund (2018) find that corporate bond mutual funds generate higher returns and attract more inflows when they reach for yield in periods of low interest rates.[27] To address this concern, we focus on a subsample of bonds whose mutual fund holding remains unchanged over the second quarter of 2020, and hence are unlikely to be traded by mutual funds in pursing higher yields.[28] If our results are driven by mutual funds reaching for yield in the post-crisis period, we should not expect mutual fund holding shares to affect muni yield spreads in this sample.

Specifically, we use a sample that spans January 2 to June 30, 2020 (again without March and April) and include only bonds whose total par amount held by mutual funds do not change from the first quarter-end to the second quarter-end in 2020. We then re-estimate Model (6.1) with both time-varying effects of bond controls and issuer-date fixed effects. Results are presented in Table 11. Column (1) shows that the coefficient of the interaction of $MF\ Share$ and $PostCrisis$ remains positive and highly significant. Its economic magnitude remains qualitatively the same compared to that reported in Column (5) of Table 8. In Column (2) we further restrict the sample by excluding bonds not held by mutual funds in any of the first two quarters of 2020 and obtain consistent results. In sum, we find no support for the argument that our results are driven by mutual funds reaching for yields in

[26] To combat the negative impacts of the Covid-19 crisis on the economy, the Federal Reserve reduced the target federal funds rate by 50 basis points on March 3, 2020, and by additional 100 basis points on March 16, 2020. The target range for federal funds rates has remained at 0-0.25% since March 16, 2020.

[27] In addition to mutual funds, other institutional investors such as insurance firms could also reach for yield in choosing their investments in corporate bonds (see Becker and Ivashina, 2015).

[28] Intuitively, to reach for yields, mutual funds would increase their holdings of higher-yield bonds and/or decrease their holdings of lower-yield bonds.

the post-crisis period.

7 Conclusion

The Covid-19 crisis provides an opportunity to examine the potential fragility risks posed by mutual funds to the muni markets, and the role played by dealers in transmitting such fragility risks. During the two weeks leading to various government interventions, municipal bond mutual funds suffer unprecedented outflows. We find strong evidence that investor redemptions destabilize the underlying muni markets. Compared to other bonds with similar characteristics, bonds held by mutual funds trade substantially more, and their yield spreads widen significantly more, especially when their holding funds suffer stronger outflows.

Such destabilizing effects of mutual fund outflows seem to have been amplified by dealers' pulling back from liquidity provision. We demonstrate how dealers shift from buying to selling in bonds that are likely facing flow-induced selling pressures at the height of the crisis. Importantly, the fragility risks posed by mutual funds seem to have changed dealer behaviors in the aftermath of the crisis. Following the stabilization of mutual fund flows, muni dealer inventories in bonds held by mutual funds continue to drift downward, whereas inventories in other bonds quickly revert to their pre-pandemic levels. As a result, liquidity deteriorates in bonds subject to greater mutual fund fragility risks. We find that the muni market seems to price in such potential fire sale risk, with bonds held more by mutual funds exhibiting wider yield spreads. The pricing effects are stronger when a bond's mutual fund holders are more exposed to the Covid-19 crisis, or have less liquid bond portfolios.

Our study underscores the need to understand and address the threats posed by mutual funds to financial stability, especially in an illiquid market dominated by retail investors. The materialization of mutual fund redemption risks at the height of the Covid-19 crisis, as well as their lasting effects on the municipal bond markets, suggest that the effect of mutual fund flows goes beyond the fund itself, and can have a broader impact on asset markets. Our results also highlight the role played by dealers in transmitting the fragility risks posed by mutual funds. The ultimate impact of bond fund outflows on the muni markets largely relies on dealers' capability of absorbing flow induced sales. Absent a Fed facility that provides a liquidity backstop as in the corporate bond markets, muni dealers are likely to curtail their liquidity provisions in bonds subject to greater fire sale risks. As a result, they amplify, rather than mitigate financial fragility posed by mutual funds.

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Figure 1: **Municipal bond yield spreads in 2020**

This figure shows the daily time series of average municipal bond yield spreads (relative to the same-maturity Treasury bond yields, adjusted for federal and state tax), in percent and based on the trading data of municipal bonds from MSRB, excluding inter-dealer trades. We exclude the following municipal bonds: those not exempt from federal tax, those issued within three months, those maturing within one year, those issued by U.S. insular areas, and those with insurance. The sample period is from January 2, 2020, to July 17, 2020.

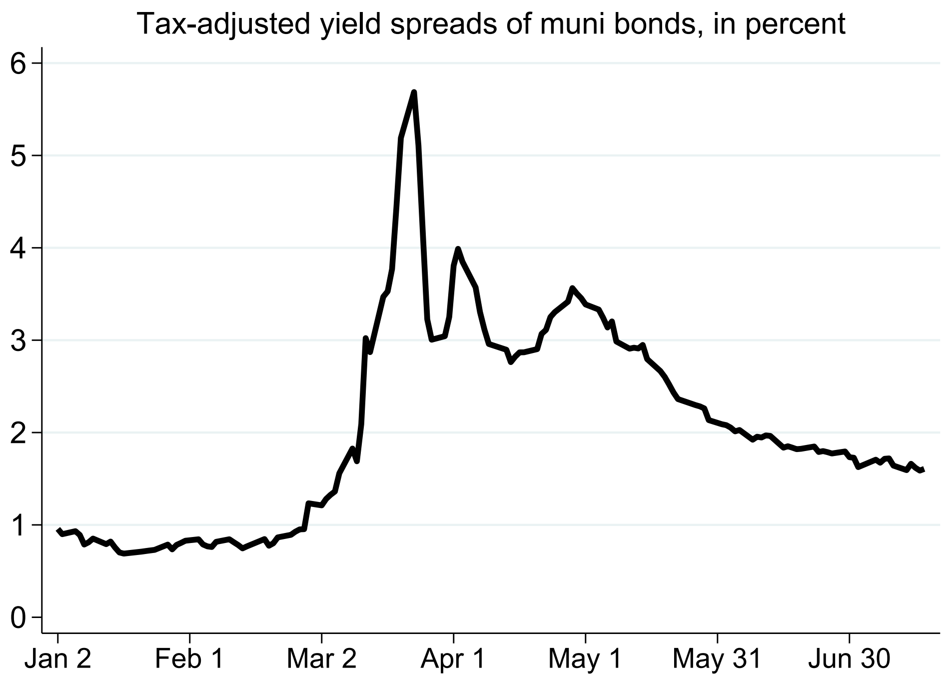


Figure 2: **AUMs and flows in municipal bond mutual funds**

The top panel of this figure shows the daily time series of total assets under management for municipal bond mutual funds, in billion dollars. The bottom panel of the figure shows the daily time series of total net flows for municipal bond mutual funds, adjusted for fund returns and in billion dollars. Both panels are based on the daily fund AUMs and returns obtained from Morningstar (428 funds in total), excluding funds without such daily information. The sample period is from January 2, 2020, to June 30, 2020.

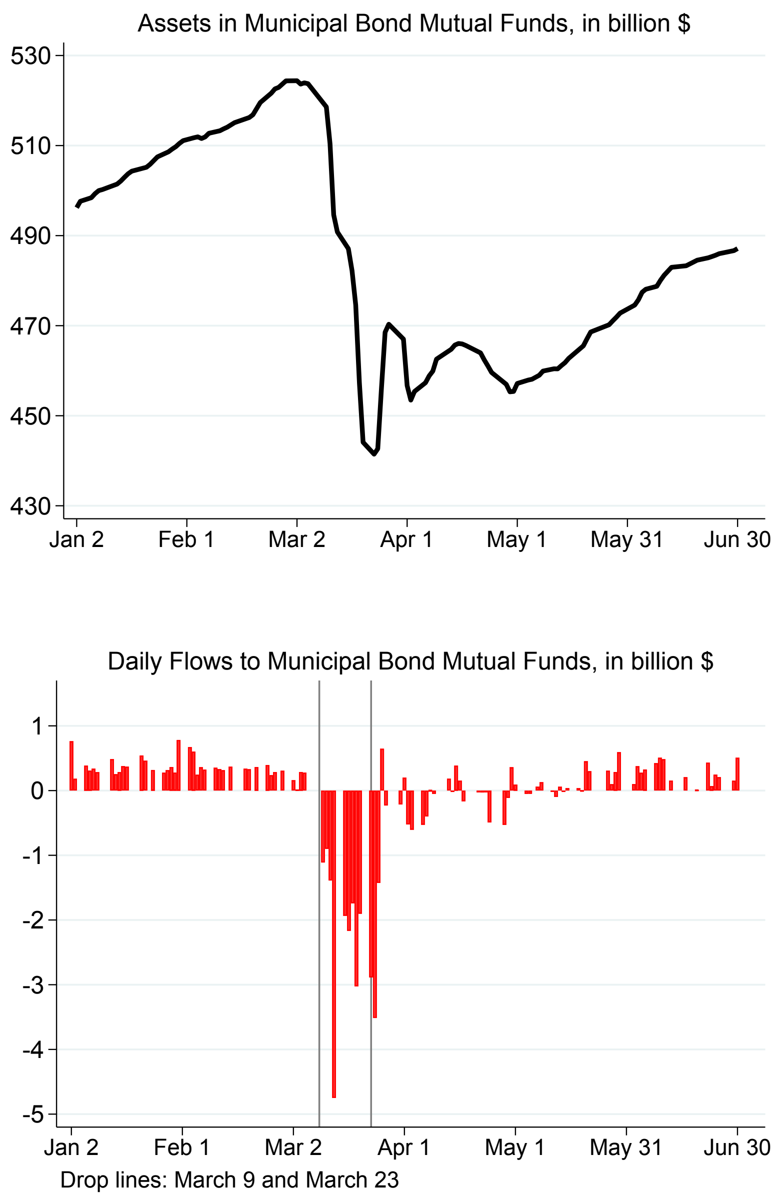
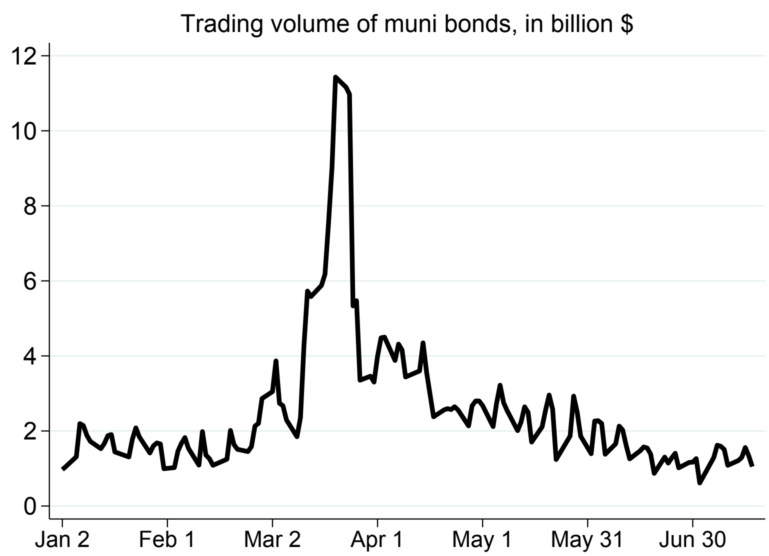


Figure 3: **Municipal bond trading volume in 2020**

The top panel shows the daily time series of total trading volume of municipal bonds, in trillion dollars. The bottom panel shows trading volumes of municipal bonds by their mutual fund ownership. The CUSIP-level mutual fund holding information is obtained from eMAXX, as of each quarter-end. Both panels are based on the trading data of municipal bonds from MSRB, excluding inter-dealer trades. We exclude the following municipal bonds: those not exempt from federal tax, those issued within three months, those maturing within one year, those issued by U.S. insular areas, and those with insurance. The sample period is from January 2, 2020, to July 17, 2020.



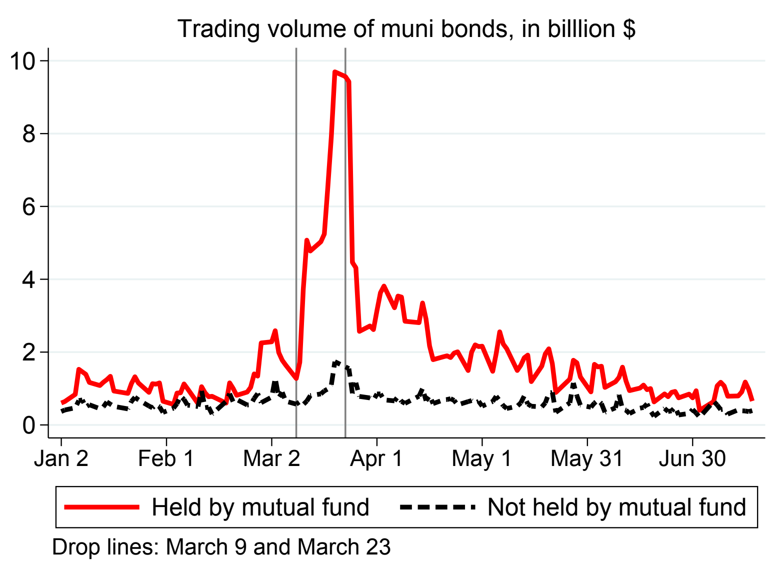


Figure 4: **Municipal bond yield spreads in 2020: by mutual fund ownership**

This figure shows the daily time series of average municipal bond yield spreads (relative to the same-maturity Treasury bond yields, adjusted for federal and state tax), in percent and based on the trading data of municipal bonds from MSRB, excluding inter-dealer trades. Tax-adjusted yield spreads are calculated separately based on bonds' mutual fund ownership. CUSIP-level mutual fund holding information is obtained from eMAXX, as of each quarter-end. We exclude the following municipal bonds: those not exempt from federal tax, those issued within three months, those maturing within one year, those issued by U.S. insular areas, and those with insurance. The sample period is from January 2, 2020, to July 17, 2020.

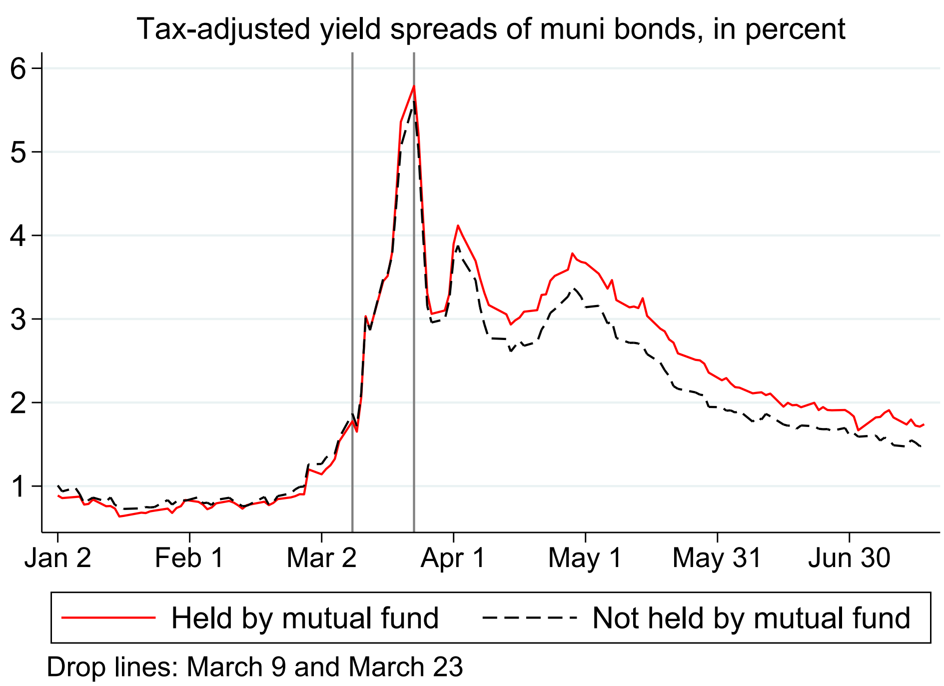


Figure 5: **Municipal bond dealer inventory in 2020: by mutual fund ownership**

This figure shows the daily time series of total dealer inventory of municipal bonds by their mutual fund ownership, cumulative from zero since January 1, 2020 and in million dollars. The CUSIP-level mutual fund holding information is obtained from eMAXX, as of each quarter-end. Dealers' cumulative inventory is calculated from the trading data of municipal bonds from MSRB, excluding inter-dealer trades. We exclude the following municipal bonds: those not exempt from federal tax, those issued within three months, those maturing within one year, those issued by U.S. insular areas, and those with insurance. The sample period is from January 2, 2020, to July 17, 2020.

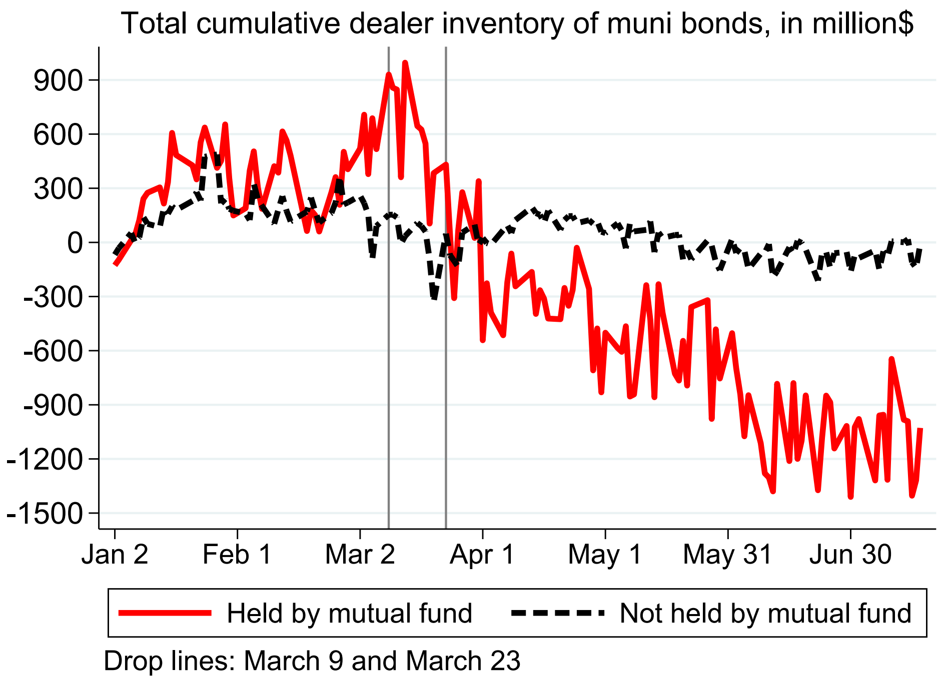


Table 1: **Summary statistics for pre-crisis municipal bonds**

This table provides summary statistics for municipal bonds traded in the first two months of 2020, divided into two groups based whether they are held by any mutual funds as of the end of 2019. Yield spread is adjusted for both federal tax and state tax. Trading volume is aggregated at date level for each bond. *MF share* stands for mutual fund share and is defined as total mutual fund holding amount as a share (in percent) of the bond's outstanding amount. We exclude the following municipal bonds: those not exempt from federal tax, those issued within three months, those maturing within one year, those issued by U.S. insular areas, and those with insurance.

	Muni bonds with mutual fund holders				**Muni bonds without mutual fund holders**			
Variable	**Bond #**	**Mean**	**Median**	**S.D.**	**Bond #**	**Mean**	**Median**	**S.D.**
Yield spread (%)	29,080	0.76	0.51	0.85	70,569	0.80	0.58	0.78
Rating	29,080	3.85	3	2.31	70,569	3.03	3	1.68
Coupon	29,080	4.80	5	0.55	70,569	4.12	4	0.96
Age (in years)	29,080	4.45	3.91	2.96	70,569	4.41	3.99	2.65
Year to maturity	29,080	10.21	8.50	7.27	70,569	8.26	7.04	5.77
Trading volume ($)	29,080	312,402	50,000	1,582,251	70,569	141,271	33,333	1,162,851
Amount outstanding ($)	29,080	26,000,000	13,900,000	41,900,000	70,569	4,185,832	2,225,000	6,329,137
MF share	29,080	0.31	0.26	0.25	70,569	0	0	0

Table 2: **Mutual fund ownership and trading volume during crisis**

The dependent variable is the logarithm of trading volume in individual municipal bond. The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from February 24 to March 20, 2020. *Crisis* is a dummy variable that equals to one for the period of March 9 to March 20, 2020. *Held by MF* is a dummy that equals to one if the bond is held by mutual funds as of the end of 2019, and *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the end of 2019) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, and logarithm of amount outstanding. *Bond controls* × *Crisis* indicates the interaction terms between the *Crisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: log(Trading volume)					
	(1)	(2)	(3)	(4)	(5)
Held by MF×Crisis	0.293***				
	(7.10)				
MF share×Crisis		0.924***	0.926***	0.907***	0.810***
		(8.02)	(8.03)	(8.23)	(7.71)
Held by MF	0.059*				
	(2.06)				
MF share		0.549***	0.548***	0.456***	0.456***
		(8.95)	(8.92)	(7.87)	(6.39)
Crisis	-0.066***	-0.058***			
	(-3.03)	(-2.96)			
Bond controls	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes		
Type FE	Yes	Yes	Yes		
Sector FE	Yes	Yes	Yes		
State FE	Yes	Yes	Yes		
Date FE			Yes	Yes	
Issuer FE				Yes	
Bond controls×Crisis					Yes
Issuer×Date FE					Yes
Adj. R^2	0.062	0.078	0.078	0.117	0.101
N of obs.	197016	197016	197016	195372	157038

Table 3: **Mutual fund flow-induced trading during crisis**

The dependent variable is the logarithm of trading volume in individual municipal bond. The bond-date sample only includes municipal bonds that are held by municipal mutual funds as of the end of 2019 and matched with fund daily flow information. The sample spans from March 9 to March 20, 2020 (i.e., the crisis period). $MF\ share$ is calculated as the share of mutual fund holdings of a municipal bond (as of the end of 2019) relative to its outstanding amount. $MF\ outflow$ is a bond-level flow measure, calculated as the average of the bond's mutual fund holders' cumulative percentage outflows over the most recent two business days, weighted by each fund's holding amount of that bond. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: log(Trading volume)				
	(1)	(2)	(3)	(4)
MF outflow	0.264***	0.221***	0.210***	0.201***
	(9.24)	(7.34)	(8.82)	(7.24)
MF share		1.450***	1.254***	1.202***
		(13.92)	(11.69)	(11.17)
Controls	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes		
Type FE	Yes	Yes		
Sector FE	Yes	Yes		
State FE	Yes	Yes		
Date FE	Yes	Yes	Yes	
Issuer FE			Yes	
Issuer×Date FE				Yes
Adj. R^2	0.075	0.101	0.157	0.147
N of obs.	27117	27117	26511	21362

Table 4: **Mutual fund flow-induced price impact during crisis**

The dependent variable is tax-adjusted yield spread of individual municipal bond, in percent. The bond-date sample only includes municipal bonds that are held by municipal mutual funds as of the end of 2019 and matched with fund daily flow information. The sample spans from March 9 to March 20, 2020 (i.e., the crisis period). $MF\ share$ is calculated as the share of mutual fund holdings of a municipal bond (as of the end of 2019) relative to its outstanding amount. $MF\ outflow$ is a bond-level flow measure, calculated as the average of the bond's mutual fund holders' cumulative percentage outflows over the most recent two business days, weighted by each fund's holding amount of that bond. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: bond yield spreads (tax-adjusted)				
	(1)	(2)	(3)	(4)
MF outflow	0.055**	0.049**	0.061***	0.074***
	(2.80)	(2.54)	(3.74)	(3.84)
MF share		0.224***	0.285***	0.298***
		(5.86)	(5.58)	(4.31)
Controls	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes		
Type FE	Yes	Yes		
Sector FE	Yes	Yes		
State FE	Yes	Yes		
Date FE	Yes	Yes	Yes	
Issuer FE			Yes	
Issuer×Date FE				Yes
Adj. R^2	0.552	0.553	0.595	0.619
N of obs.	27117	27117	26511	21362

Table 5: **Mutual fund ownership and dealer intermediation during crisis**

The dependent variable is daily dealer net purchase (i.e., net change in dealer inventory) of individual municipal bond, in million dollars. The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from February 24 to March 20, 2020. *Crisis* is a dummy variable that equals to one for the period of March 9 to March 20, 2020. *Held by MF* is a dummy that equals to one if the bond is held by mutual funds as of the end of 2019. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the end of 2019) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond controls* × *Crisis* indicates the interaction terms between the *Crisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: Dealer net purchase					
	(1)	(2)	(3)	(4)	(5)
Held by MF×Crisis	-0.019***				
	(-3.73)				
MF share×Crisis		-0.062***	-0.062***	-0.058***	-0.038**
		(-3.46)	(-3.39)	(-3.09)	(-2.64)
Held by MF	0.009**				
	(2.49)				
MF share		0.034***	0.035***	0.032***	0.027**
		(3.47)	(3.57)	(3.00)	(2.44)
Crisis	-0.009	-0.010			
	(-1.46)	(-1.64)			
Bond controls	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes		
Type FE	Yes	Yes	Yes		
Sector FE	Yes	Yes	Yes		
State FE	Yes	Yes	Yes		
Date FE			Yes	Yes	
Issuer FE				Yes	
Bond controls×Crisis					Yes
Issuer×Date FE					Yes
Adj. R^2	0.003	0.003	0.006	-0.029	-0.031
N of obs.	197016	197016	197016	195372	157038

Table 6: **The aftermath: dealer inventory**

The dependent variable is cumulative dealer inventory of individual municipal bond since January 2, 2020, in million dollars. The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from January 2 to July 17, 2020 (excluding March and April). *PostCrisis* is a dummy variable that equals to one for the period of May 1 to July 17, 2020, and zero otherwise. *Held by MF* is a dummy that equals to one if the bond is held by mutual funds as of the most recent quarter-end. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond controls* × *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: Cumulative dealer inventory					
	(1)	(2)	(3)	(4)	(5)
Held by MF×Post-crisis	-0.267***				
	(-6.87)				
MF share×Post-crisis		-0.858***	-0.859***	-0.846***	-0.552***
		(-5.60)	(-5.61)	(-5.30)	(-3.51)
Held by MF	0.162***				
	(4.60)				
MF share		0.386***	0.387***	0.416***	0.192*
		(4.48)	(4.49)	(4.45)	(1.97)
Post-crisis	-0.053***	-0.066***			
	(-6.84)	(-4.46)			
Bond controls	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes		
Type FE	Yes	Yes	Yes		
Sector FE	Yes	Yes	Yes		
State FE	Yes	Yes	Yes		
Date FE			Yes	Yes	
Issuer FE				Yes	
Bond controls×Post-Crisis					Yes
Issuer×Date FE					Yes
Adj. R^2	0.009	0.010	0.010	0.102	-0.022
N of obs.	702372	702372	702372	701189	531024

Table 7: **The aftermath: muni market liquidity**

The dependent variable is size-matched realized bid-ask spread measure of individual municipal bond. The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from January 2 to July 17, 2020 (excluding March and April). $Freq > 10$ ($Freq > 20$) indicates that the subsample only includes bonds trade on more than 10 (20) days over the sample period. *PostCrisis* is a dummy variable that equals to one for the period of May 1 to July 17, 2020, and zero otherwise. *Held by MF* is a dummy that equals to one if the bond is held by mutual funds as of the most recent quarter-end. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond controls* × *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: Size-matched bid-ask spread						
					Freq>10	**Freq>20**
	(1)	(2)	(3)	(4)	(5)	(6)
Held by MF×Post-crisis	0.028***					
	(3.32)					
MF share×Post-crisis		0.051*	0.046*	0.062*	0.181***	0.260**
		(1.97)	(1.87)	(1.87)	(3.15)	(2.62)
Held by MF	-0.048***					
	(-5.93)					
MF share		-0.183***	-0.164***	-0.153***	-0.293***	-0.374***
		(-7.60)	(-7.45)	(-5.60)	(-6.81)	(-4.60)
Post-crisis	0.118***	0.125***				
	(9.22)	(10.07)				
Bond controls	Yes	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes				
Type FE	Yes	Yes				
Sector FE	Yes	Yes				
State FE	Yes	Yes				
Date FE			Yes			
Issuer FE			Yes			
Bond controls×Post-Crisis				Yes	Yes	Yes
Issuer×Date FE				Yes	Yes	Yes
Adj. R^2	0.271	0.273	0.327	0.338	0.358	0.381
N of obs.	122408	122408	119818	62202	24534	9837

Table 8: **The aftermath of mutual fund fire sales: yield spreads**

The dependent variable is tax-adjusted yield spread of individual municipal bond, in percent. The full sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from January 2 to July 17, 2020 (excluding March and April). *PostCrisis* is a dummy variable that equals to one for the period of May 1 to July 17, 2020, and zero otherwise. *Held by MF* is a dummy that equals to one if the bond is held by mutual funds as of the most recent quarter-end. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond Controls* × *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: bond yield spreads (tax-adjusted)					
	(1)	(2)	(3)	(4)	(5)
Held by MF×Post-crisis	0.337***				
	(18.97)				
MF share×Post-crisis		1.166***	1.149***	1.153***	0.401***
		(23.68)	(23.90)	(25.98)	(16.36)
Held by MF	-0.186***				
	(-10.83)				
MF share		-0.573***	-0.569***	-0.464***	0.012
		(-11.44)	(-11.48)	(-10.56)	(0.90)
Post-crisis	1.132***	1.138***			
	(15.00)	(14.73)			
Bond controls	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes		
Type FE	Yes	Yes	Yes		
Sector FE	Yes	Yes	Yes		
State FE	Yes	Yes	Yes		
Date FE			Yes	Yes	
Issuer FE				Yes	
Bond controls×Post-Crisis					Yes
Issuer×Date FE					Yes
Adj. R^2	0.538	0.542	0.624	0.682	0.743
N of obs.	702372	702372	702372	701189	531024

Table 9: **The pricing of mutual fund fragility risks: subsample analysis**

The dependent variable is tax-adjusted yield spread of individual municipal bond, in percent. The full sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from January 2 to July 17, 2020 (excluding March and April). Columns (1)–(2) use subsamples defined by bond rating, with Column (1) including bonds rated as A, BBB, and high-yield, and Column (2) including bonds rated as AAA and AA. Columns (3)–(4) use subsamples defined by bond type, with Column (3) including non-GO bonds, and Column (4) including GO bonds. Columns (5)–(6) use subsamples defined by bond sector, with Column (5) including bonds in the sectors hit more by the Covid-19 crisis, including health& nursing, leisure, or transportation, and Column (6) including other bonds. $PostCrisis$ is a dummy variable that equals to one for the period of May 1 to July 17, 2020, and zero otherwise. $MF\ share$ is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. $Bond\ Controls \times PostCrisis$ indicates the interaction terms between the $PostCrisis$ dummy and bond controls. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: bond yield spreads (tax-adjusted)						
	By bond rating		**By bond type**		**By bond sector**	
	Low	**High**	**non-GO**	**GO**	**Covid**	**Other**
	(1)	(2)	(3)	(4)	(5)	(6)
MF share×Post-crisis	0.408***	0.090***	0.485***	0.080***	0.418***	0.323***
	(8.41)	(5.24)	(16.41)	(2.78)	(7.25)	(13.16)
MF share	0.025	-0.026*	0.049***	-0.056**	0.124***	-0.009
	(0.87)	(-1.95)	(3.08)	(-2.13)	(4.25)	(-0.57)
Bond controls	Yes	Yes	Yes	Yes	Yes	Yes
Bond controls×Post-Crisis	Yes	Yes	Yes	Yes	Yes	Yes
Issuer×Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.753	0.697	0.731	0.775	0.748	0.736
N of obs.	142544	382423	374826	152567	113903	411003

Table 10: **Fragility sources and the pricing of mutual fund fragility risks: Triple-difference approach**

The dependent variable is tax-adjusted yield spread of municipal bonds, in percent. This bond-date sample only includes municipal bonds that are held by mutual funds, and spans from January 2 to July 17, 2020 (excluding March and April). Bond-day observations are sorted into two subsamples based on the bond's mutual fund holders' average fragility levels, weighted by each fund's holding amount of that bond. Fund-level fragility is proxied by the fund's share of muni bond holdings in Covid-hit sectors including transportation, health & nursing care, and leisure (Columns 1–2), fund's average portfolio maturity (Columns 3–4), and fund's average portfolio rating (Columns 5–6), as of the most recent quarter-end. *PostCrisis* is a dummy variable that equals to one for the period of May 1 to July 17, 2020, and zero otherwise. MF *share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond Controls* $\times$ *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond issuer is identified by the first 6 characters/digits of its CUSIP. *p-value of the difference* indicates the p-value from testing the difference in the estimated coefficients on MF *Share* $\times$ *PostCrisis* across two subsamples. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Dependent variable: bond yield spreads (tax-adjusted)					
	MF holders' Covid exposure		**MF holders' portfolio maturity**		**MF holders' portfolio rating**	
	Large (1)	**Small** (2)	**Long** (3)	**Short** (4)	**Low** (5)	**High** (6)
MF share×Post-crisis	0.511***	0.170***	0.571***	0.216***	0.529***	0.128***
	(8.99)	(4.57)	(9.77)	(7.44)	(9.22)	(4.01)
MF share	0.105***	0.030*	0.101***	-0.013	0.115***	0.007
	(2.82)	(1.72)	(2.95)	(-0.85)	(3.23)	(0.43)
Bond controls	Yes	Yes	Yes	Yes	Yes	Yes
Bond controls×Post-Crisis	Yes	Yes	Yes	Yes	Yes	Yes
Issuer×Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.761	0.790	0.756	0.830	0.752	0.801
N of obs.	114036	117572	109992	120152	112412	119641
p-value of the difference	0.000		0.000		0.000	

Table 11: **Test alternative explanation: mutual funds reaching for yield**

The dependent variable is tax-adjusted yield spread of individual municipal bond, in percent. We only include muni bonds whose total holding amount by mutual funds is unchanged from the end of 2020:Q1 to the end of 2020:Q2. Column (2) further excludes bonds that are not held by any mutual funds at these two quarter-ends. The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from January 2 to June 30, 2020 (excluding March and April). $PostCrisis$ is a dummy variable that equals to one for the period of May 1 to June 30, 2020, and zero otherwise. $MF\ share$ is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. $Bond\ controls \times PostCrisis$ indicates the interaction terms between the $PostCrisis$ dummy and bond controls. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: bond yield spreads (tax-adjusted)		
	All unchanged (1)	**Held by MFs** (2)
MF share×Post-crisis	0.381***	0.405***
	(13.09)	(10.28)
MF share	-0.041***	0.047**
	(-2.89)	(2.50)
Bond controls	Yes	Yes
Bond controls×Post-Crisis	Yes	Yes
Issuer×Date FE	Yes	Yes
Adj. R^2	0.732	0.768
N of obs.	371180	133301