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

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Abstract

We study the period around the Covid-19 crisis to examine the potential fragility risks posed by mutual funds to the municipal bond market and the role played by dealers in transmitting such fragility risks. Induced by 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. Importantly, such destabilizing effects have reshaped market perceptions on the fragility risks posed by mutual funds. In the aftermath of the muni crisis, dealers reduce their inventories in bonds held by mutual funds and yield spreads reflect a "fire sale" premium in these bonds, especially when they are held by mutual funds with greater 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. 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 concern regarding potential financial stability risks of fixed income mutual funds.[1]

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) and 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. Such massive redemptions led to extraordinary trading dynamics, and our paper provides the first empirical analysis of the immediate and lasting effects of mutual fund fragility risks in the muni market. A novel feature of our analysis is our focus on the role of dealer liquidity provisions in transmitting mutual fund fragility risks. 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. If, as we show happened, dealers curtail liquidity provision, then the instability in mutual funds

[1] 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. There is also an academic literature on strategic complementarities among mutual fund investors and financial fragility, with notable papers by Chen, Goldstein, and Jiang (2010), Goldstein, Jiang, and Ng (2017), and Zeng (2017).

translates into instability in the underlying, and these destabilizing effects can persist even after the normalization of muni fund flows. Indeed, we find that in the aftermath of the muni crisis, dealers continued to reduce their inventories in bonds held by mutual funds and yield spreads widen notably in these bonds, 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. Certainly, the Covid-19 crisis has 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 allows 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 primarily by retail 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 virtually identical to that of issues not held by funds before the crisis, diverges both during and after the crisis.

Our research provides a number of results. We show how the municipal bond market experienced extreme stress during the Covid-19 crisis, with trading volume increasing six-fold (almost entirely driven by the trading of bonds held by mutual funds) and tax-adjusted yield spreads soaring from less than 1% in late February, to almost 6% by March 23 (Figure 1). We demonstrate how dealer inventory behavior shifted from buying to selling at the height of the crisis, particularly for bond issues held by mutual funds, further exacerbating pressures in the muni bond market. Transaction costs for municipal bond trades soared amid dealer net selling, especially in bonds held by mutual funds. Moreover, we show that a muni bond experiences more intensive trading and larger price depression when its mutual fund holders have suffered larger redemptions. Our analysis here provides some of the first evidence of the impact of mutual fund redemptions on the municipal bond market during the Covid-19 crisis.

Following multiple Federal Reserve and Congressional actions to improve muni market functioning and aid municipalities, muni market conditions started to improve. Trade volumes in bonds quickly normalized, transaction costs declined, and muni mutual funds started to attract persistent inflows since May.[2] We then focus on the post-crisis period (May to July) and investigate the lasting market effects induced by potential mutual fund fire sale risks. Unlike in corporate bonds where Fed actions led dealers to resume accumulating inventories (O'Hara and Zhou (2020a)), we show that muni bond dealer inventories in bonds held by mutual funds continue to drift downward in the post-crisis period, while inventories in other bonds quickly revert to their pre-pandemic levels. Such reluctance to intermediate bonds held by mutual funds also drives up the relative trading costs of such bonds in the post-crisis period. The absence of a Fed facility focused on the secondary market liquidity provision may have affected dealers' willingness to hold inventory in bonds with potential mutual fund fire sale risks.

Finally, and perhaps most important, we find that fragility risks posed by mutual funds are priced in municipal bond yields in the post-crisis period. We show that a wedge persists

[2]Muni liquidity dynamics around these policy actions are consistent with theoretical discussions on the impact of government interventions on liquidity provisions during crises by Weill (2007) and Lagos, Rocheteau, and Weill (2011).

between the yield spreads of bonds held by mutual funds and those that are not. The effects of mutual fund ownership on municipal bond yield spreads, on the order of 34 basis points, are more pronounced when the assets of the bond's mutual fund holders are more exposed to the Covid-19 crisis, have longer maturity, or less liquid.[3] We provide extensive testing to examine the channel for this effect, with our results supporting that dealers' reluctance to intermediate bonds with potential mutual fund fragility risks could play a role in driving the wedge. Our findings demonstrate that the effect of mutual fund redemption-induced selloffs on the underlying market can persist long after the fire sales cease, especially when the market lacks an effective liquidity backstop.

In sum, our results provide strong evidence of mutual fund associated market fragility and dealers' role in channeling it—we show how mutual fund redemptions undermined stability in the underlying market during the crisis and, more intriguing, how such fragility risks have reshaped market perceptions and introduced what appears to be a "fire sale premium" incorporated in muni pricing in the post-crisis period.

Our paper makes a number of contributions to the literature. First, existing studies on the fragility risks associated with fixed income mutual funds largely focus on how liquidity transformation conducted by these funds could generate a strong first-mover advantage among their investors in adverse situations and trigger large-scale redemptions, leading to dynamics similar to a bank run as in Diamond and Dybvig (1983). Chen, Goldstein, and Jiang (2010) model strategic complementarities among mutual fund investors, the effects of which are stronger for less liquid funds. They show that less liquid funds could suffer disproportionally larger-scale redemptions when a negative shock hits. Consistent empirical evidence for corporate and municipal bond mutual funds is provided in Goldstein, Jiang, and Ng (2017).[4] Falato, Goldstein, and Hortaçsu (2020) study fund flows in corporate bond

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

[4] Chen, Goldstein, and Jiang (2010) also show that outflows are more sensitive to bad performance for illiquid equity funds. 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).

mutual funds during the recent Covid-19 crisis and find that illiquidity of fund assets and the vulnerability to fire sales are important factors in explaining outflows. Zeng (2017) demonstrates that a mutual fund's expected cash-rebuilding following outflows can generate further first-mover advantage and lead to amplified investor runs.

A few recent papers analyze whether investor redemptions lead to fire sales and price depressions in the corporate bond markets (Feroli, Kashyap, Schoenholtz, and Shin (2014); Jiang, Li, and Wang (2017); Choi, Hoseinzade, Shin, and Tehranian (2020); Falato, Hortacsu, Li, and Shin (2020); and Ma, Xiao, and Zeng (2020)). Jiang, Li, Sun, and Wang (2020) show that asset illiquidity of corporate bond mutual funds can cause more volatility in the corporate bond markets through the channel of flow-induced selling pressures. Our paper contributes to this literature by showing how the materialization of mutual fund fragility risks during a major crisis destabilizes the underlying markets. More importantly, by examining dealer behavior when facing large mutual fund outflows, our paper is the first to show how (lack of) dealer intermediation could exacerbate fragility risks posed by mutual funds. 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 both the liquidity and the pricing of municipal bonds.

Second, our paper helps improve our understanding of the role played by dealers in the functioning of fixed income markets. A large number of 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.[5] In the muni market, several

[5]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).

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 dealer liquidity provisions are affected by their perceptions of fragility risks posed by mutual funds, and how their pulling back from mutual fund held bonds could 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)), our results show that liquidity could play a magnifying role in municipal bond pricing when market is under stress.

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 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)).[6] 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 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 highlight the significance of the Fed's new role as market maker of last resort.

This paper is organized as follows. Section 2 gives a brief overview of municipal bond trading. Section 3 discusses the data in the paper. Section 4 analyzes the crisis period, examining the impact of mutual fund redemptions on dealer liquidity provision, trading

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

volume, and yield spreads in the underlying bond market, and differentiating these effects on bond issues held (and not held) by mutual funds. Section 5 analyzes the after-crisis period, examining how dealers' behaviors and liquidity conditions change for bonds with higher mutual fund fragility risks, and testing for whether fragility risks are priced in municipal bond yield spreads. We also explore sources of mutual fund fragility risk and conduct additional analyses to rule out alternative explanations for our findings. Section 6 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 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.[7] 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

[7] 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).

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.[8] 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 (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).

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

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.[9]

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.[10] Given the large number of municipal bonds, the holdings of municipal

[9] 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.

[10] We include both municipal bond mutual funds and balanced bond funds (that hold at least 25 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.[11]

4 Mutual fund runs and dealer intermediation during the Covid-19 crisis

We start by analyzing the recent Covid-19 crisis during which substantial fragility risks materialized. In particular, we examine trading activities across municipal bonds with different exposures to mutual fund runs at the height of the crisis. We analyze how muni dealers respond to potential heightened demand for liquidity from mutual funds. And finally, we explore the impact of such fund flow induced trading on liquidity and yield spreads of municipal bonds.

bonds as of the end of 2019), but exclude municipal money market funds.

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

4.1 Mutual fund ownership and bond trading activities during 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).[12] 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 were likely under more severe stress. If muni investors' decisions to trade certain group of bonds are 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

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

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 $25.7 million and $322 thousand respectively, substantially larger than those for other bonds, which are only $4.1 million and $140 thousand. In addition, compared to other bonds, those held by mutual funds are rated slightly lower and carry a somewhat higher coupon rate.[13] There is little difference in age between the two groups of municipal bonds, while the mean number of years to maturity is about 10.5 years for mutual fund invested bonds, higher than that for other bonds (8.4 years).

To test formally whether mutual fund ownership, rather than other bond characteristics, drives the drastic surge in municipal bond trading volume during the Covid-19 crisis, we use a sample that includes both the two-week crisis period (from March 9 to March 20) and a pre-crisis period of the same length (from February 24 to March 6).[14] We estimate the following empirical model:

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

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 reported in Table 1, including the numeric composite credit rating (*Rating*), coupon rate (*Coupon*), number of years since issuance (*Age*), number of years to maturity (*Year to Maturity*), and the logarithm of total par amount outstanding

[13] Since a bond can be rated by multiple rating agencies, we assign a composite rating to each bond on each day. Specifically, we give a numeric value to each notch of S&P/Moody's/Fitch credit rating, with 1, 2, 3, 4 denoting AAA/Aaa/AAA, AA+/Aa1/AA+, AA/Aa2/AA, AA-/Aa3/AA-, respectively. 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.

[14] 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.

(log(*Amount Outstanding*)).

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 lies 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.[15] 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.[16] 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.[17] 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 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%).

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

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

[17]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.

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 they accounting for 36% of bond-day observations in our sample. Finally, we include day fixed effects (μ_t) to control for general trends in muni market trading. Standard errors are clustered at the bond and date levels.

Results in Table 2 show that bonds held by mutual funds traded more heavily during the crisis period. The coefficient of *Held by MF* is 0.061 (significant at the 5% level), implying that prior to the crisis, bonds held by mutual funds are traded somewhat more than other bonds (Column (1)). Importantly, the coefficient of the interaction of *Held by MF* and *Crisis* is much larger in magnitude (0.29) and significant at the 1% level, suggesting that compared to other bonds, those held by mutual funds experience an additional 29% increase in trading activities during the crisis period.

Geographic differences in the transmission of the virus, the actions taken to fight the virus, and the resulting economic slowdown, could all affect bonds differentially over time. To control for potential time-varying impacts on the trading activities of bonds with different types, in different sectors, and issued in different states, we include into model (4.1) three two-way fixed effects: bond type × date fixed effects, bond sector × date fixed effects, and bond state × date fixed effects. As shown in Column (2), the coefficient of the interaction of *Held by MF* and *Crisis* changes little and remains positive and highly significant. This finding reinforces 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.

If the drastic increase in trading activities can indeed be attributed to mutual funds selling to meet redemption requests, then we would expect the additional trading of a bond during the crisis period to increase in the levels of its mutual fund ownership. To test this hypothesis, we calculate *MF share*, which is defined as the share of a bond's outstanding amount held by mutual funds at the end of 2019. We then replace the dummy *Held by MF* with MF *share* and re-estimate Model (4.1). Consistent with our hypothesis, Column (3) 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 potential time varying impacts of the evolution of the pandemic on different kinds of bonds does not change our results (Column (4)).

4.2 Dealer intermediation and municipal bond liquidity during crisis

Whether liquidity demands from mutual funds pose a threat to bond market stability depends in large part on dealers' liquidity provision. The muni market could withstand large sell-offs by mutual funds if dealers step up to absorb these sales. While a number of papers have studied dealers' liquidity provisions in the corporate bond markets, especially during stress times (see, for examples, 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)), little is known about how dealers respond to excessive selling pressures in the muni markets during market stress.

To understand the role dealers play in transmitting mutual fund fragility risks, we study dealer trading behavior and the resulting inventory changes around the crisis period. Figure 4 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 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%, while those in other bonds continue their gradual decline since late February. This finding suggests that although 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. Rather, 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 formally test these effects, we measure dealers' 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:

$$\begin{aligned} Dealer\ Net\ Purchase_{i,t} = \alpha + \beta_1 \times MF\ Share_{i,t} + \beta_2 \times Crisis_t \times MF\ Share_{i,t} \\ + \gamma \times X_{i,t} + \mu_{type} + \mu_{sector} + \mu_{state} + \mu_t + \epsilon_{i,t}, \quad (4.2) \end{aligned}$$

where $MF\ Share_{i,t}$ refers to the share of a bond i's outstanding amount held by mutual funds at the end of 2019. All the other variables are defined as in Model (4.1).

Consistent with the overall patterns observed in Figure 4, Column (1) of Table 3 shows that the coefficient of $MF\ Share$ is positive and highly significant, suggesting that dealers accumulate greater inventories in bonds held more heavily by mutual funds during the pre-crisis period. Moreover, the interaction of $MF\ Share$ and $Crisis$ is not only negative and highly significant, but also carries a substantially larger magnitude compared with the coefficient of $MF\ Share$. This result implies that dealers' inventories decline more in bonds that are likely facing greater selling pressures from mutual funds in the crisis period. Controlling for potential time-varying impacts of the evolution of the Covid-19 pandemic does not change our results (Column (2)).

How does muni market liquidity move with the pullback by dealers when facing large selloffs by mutual funds? To address this question, we adopt a transaction cost measure as in Hendershott and Madhavan (2015). Specifically, we capture a municipal bond's transaction cost by measuring its price impact, and we use the closest in time inter-dealer trade in that bond as a benchmark price:

$$Cost_j = \ln(Trade\ Price_j / Benchmark\ Price_j) \times Trade\ Sign_j, \tag{4.3}$$

where $Trade\ Price_j$ refers to the transaction price for a customer trade j, $Benchmark\ Price_j$ is the transaction price for the prior interdealer trade, and $Trade\ Sign_j$ is an indictor variable for whether the customer is buying or selling from the dealer. $Trade\ Sign_j$ takes the value of $+1$ for a customer purchase and -1 for a customer sale. We multiply $Cost_j$ by 100 to compute transaction cost in percent. Given that most municipal bonds trade only sporadically, we require the benchmark inter-dealer trade to occur within one week prior to the customer trade. To reduce potential noise in the transaction cost measures, we remove negative cost estimates and winsorize non-negative cost measures at the top 1% level.

As shown in Figure 5, muni market liquidity deteriorates precipitously. In January and February, average transaction costs in bonds held by mutual funds are largely the same as those in other bonds. However, in early March, transaction costs in both groups of bonds climb higher, with those in bonds held by mutual funds increasing substantially faster. The gap in transaction costs between the two groups of bonds widens sharply and peaks at 25 basis points right before the Federal Reserve announces a series of credit and liquidity facilities to ease market conditions.

These overall movements in muni market liquidity, however, could suffer from potential selection biases. As the transaction cost measure can only be estimated for bond-days with completed trades, average transaction costs plotted in Figure 5 could reflect time series changes in the sample of bonds used for estimation. To control for potential sample selection biases, as well as the impact of bond characteristics on liquidity, we continue to focus on the sample that spans both the pre-crisis and the crisis periods and re-estimate Model (4.2) by replacing $Dealer\ Net\ Purchase_{i,t}$ with $Cost_{i,t}$, which is the volume weighted average cost for trades in bond i on day t.

Results in Column (3) of Table 3 show that muni market liquidity deteriorates more in bonds that are likely facing large sell-offs by mutual funds during the crisis. Although transaction costs are lower in bonds held more by mutual funds during the pre-crisis period, they increase significantly more in these bonds during the crisis period. The coefficient of the interaction of $MF\ Share$ and $Crisis$ declines somewhat when controlling for two-way fixed effects, suggesting that the evolution of the pandemic could have imposed different liquidity effects on different bonds over time. Nevertheless, this coefficient remains positive and highly significant. These results highlight the potential liquidity strains arising from the interplay of mutual fund redemptions and dealer pullbacks when markets are under stress.

4.3 Mutual fund flow-induced trading and price impact during crisis

So far, we use the share of a bond's outstanding amount held by mutual funds, i.e., $MF\ Share$, to proxy for the potential fire sales risks that mutual funds can introduce to that bond. To address the concern that holding share by mutual funds might not be sufficient to capture the potential sell-offs due to fund redemptions, we establish the link between mutual fund outflows and muni trading through mutual funds' CUSIP-level holding information. We then test whether a bond experiences more intensive trading when its mutual fund holders face larger redemptions in recent days.

Specifically, we focus on 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). As a baseline, we start by estimating the following empirical model:

$$\log(Trading\ Volume_{i,t}) = \alpha + \beta_1 \times MF\ Share_{i,t} + \gamma \times X_{i,t} + \mu_{type} + \mu_{sector} + \mu_{state} + \mu_t + \epsilon_{i,t}, \quad (4.4)$$

where the dependent variable is the logarithm of trading volume in municipal bond i on day t, $MF\ Share_{i,t}$ refers to the share of a bond i's outstanding amount held by mutual funds at the end of 2019, and all the other variables are defined as in Model (4.1). Standard errors are clustered at the bond and date levels.

Consistent with our earlier findings, Column (1) of Table 4 shows that during the crisis period, trading volume is substantially higher for bonds held more by mutual funds. To flesh out the impact of mutual fund flows on municipal bond trading activities, we then construct a bond-level mutual fund flow measure, $3Day\ Outflow_{i,t}$, which is defined as:

$$3Day\ Outflow_{i,t} = \frac{\sum_{k=1}^{K} Holding\ Amount_{i,k} \times Outflow_{k,t-2,t}}{\sum_{k=1}^{K} Holding\ Amount_{i,k}}, \quad (4.5)$$

where $Outflow_{k,t-2,t}$ is fund k's cumulative percentage outflows (adjusted for fund returns) over the most recent three business days (i.e., from day $t-2$ to 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. Therefore, $3Day\ Outflow_{i,t}$ represents on average how much outflow bond i's mutual fund holders have suffered over the most recent three business days, weighted by each investing fund's holding amount of that bond.

We then include both $3Day\ Outflow$ and its interaction with $MF\ Share$ as additional explanatory variables and re-estimate Model (4.4). If trading increases in bonds held more heavily by mutual funds (i.e., with higher $MF\ Share$), we should expect this trading activity to increase more when the holding funds experience larger outflows. Indeed, as Column (2) of Table 4 shows, the coefficient of the interaction of $MF\ Share$ and $3Day\ Outflow$ is positive and highly significant, suggesting that higher trade volume in bonds held by mutual funds is likely induced by fund outflows. The coefficient of $3Day\ Outflow$ is not significant, as outflows from mutual funds affect trading in a bond only when they hold a non-zero share in the bond. Again, controlling for time-varying effects of the pandemic does not change our results (Column (3)). Together, these results lend support to using the $MF\ Share$ measure in capturing potential fire sales risks originating from mutual fund outflows.

Our results show that mutual fund outflows induced excessive trading in the muni market during the crisis time. Such trading pressure, accompanied by dealers' unwillingness to absorb shocks, could further exacerbate market conditions and depress municipal bond prices. To analyze the potential price impact of mutual fund flow-induced trading, we focus on the crisis period and estimate the following empirical model for bonds held by mutual funds:

$$\begin{aligned} Yield\ Spread_{i,t} = \alpha + \beta_1 \times MF\ Share_{i,t} + \\ \gamma \times X_{i,t} + \mu_{type} + \mu_{sector} + \mu_{state} + \mu_t + \epsilon_{i,t}, \quad (4.6) \end{aligned}$$

where the dependent variable is 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). All other variables are defined as in Model (4.4) and standard errors are clustered at the bond and date levels.

Table 5 shows that mutual fund flow-induced trading is likely to have pushed yield spreads higher during the crisis period. Column (1) shows that $MF\ Share$ has a significantly positive coefficient, suggesting that among bonds with mutual fund holders, those held more heavily by mutual funds experience larger increases in yield spreads during the crisis time. We also include $3Day\ Outflow$ and its interaction with $MF\ Share$ as additional explanatory variables and re-estimate Model (4.6). Column (2) shows that the coefficient of the interaction term is positive and significant, suggesting that large mutual fund redemptions exert substantial price pressure on munis during the crisis. This finding points to the potential destabilizing effects of mutual funds flows on the muni market. Our results change little when controlling for various two-way fixed effects (Column (3)).

5 The aftermath of the crisis

Given our findings of the destabilizing effects of muni fund runs and the accompanying sell-offs on muni prices during the crisis period, we now explore whether such fragility risks carry pricing implications even after the stabilization of mutual fund flows. We focus on the post-crisis period and start by examining how dealers' behaviors and liquidity conditions changed for bonds with higher exposures to potential mutual fund fragility risks. We then directly test whether fragility risks are priced in muni yield spreads. We also explore several sources of mutual fund fragility risks stemming from funds' portfolio exposures and examine how they affect muni prices. Finally, we conduct additional analyses to rule out alternative explanations for our findings.

5.1 Dealer liquidity provision in the post-crisis era

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 particular, muni fund flows largely normalize in April, and in May muni funds start to attract consecutive inflows (Figure 2). Interestingly, dealers continue to lower their inventories in bonds held by mutual funds after the stabilization of mutual fund flows (Figure 4). Over our sample period from the start of 2020 to July 17, 2020, dealers' cumulative inventories in these 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.[18] O'Hara and Zhou (2020a) find that as in the muni markets, dealers are net sellers

[18] 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).

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 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, municipal-oriented facilities 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. Consistent with dealers' unwillingness to intermediate municipal bonds exposed to greater mutual fund fragility risks, transaction costs in bonds held by mutual funds remain elevated compared to other bonds after April (Figure 5).

We formally test whether dealers reduce their inventories on bonds bearing potential mutual fund fragility in the post-crisis era, and whether such bonds incur higher transaction costs. We use a bond-day sample spanning from January 2 to July 17, 2020 (excluding March and April) and estimate the following empirical model:

$$\begin{aligned} Cumu\ Inv\ Chg_{i,t} &= \alpha + \beta_1 \times PostCrisis_t + \beta_2 \times MF\ Share_{i,t} + \\ &\beta_3 \times PostCrisis_t \times MF\ Share_{i,t} + \gamma \times X_{i,t} + \mu_{type} + \mu_{sector} + \mu_{state} + \mu_t + \epsilon_{i,t}, \quad (5.1) \end{aligned}$$

where $Cumu\ Inv\ Chg_{i,t}$ refers to the cumulative dealer inventory changes in bond i since the beginning of 2020. $MF\ Share_{i,t}$ is the share of a bond i's outstanding amount held by mutual funds at the most recent quarter-end. $PostCrisis_t$ is a dummy that takes the value one for the period from May 1 to July 17, 2020. $X_{i,t}$ represents a set of bond characteristics, including the numeric composite credit rating, coupon rate, number of years since issuance, number of years to maturity, the logarithm of total par amount outstanding, and the logarithm of trading volume. Bond type, sector, and state fixed effects are all controlled for, and standard errors are clustered at the bond and date levels.

We exclude March and April from our 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 have experienced persistent inflows since the start of May (as they did in January and February), we have no reasons 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 the lingering credit concerns have reshaped dealers' and investors' perceptions of the potential fragility risks posed by municipal mutual funds.

Results presented in the first three columns of 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 that the coefficient of $PostCrisis$ is negative and highly significant, suggesting that compared to their levels in January and February, dealers' cumulative inventories of municipal bonds were lower in the post-crisis period. More importantly, even after the stabilization of fund flows, dealers' cumulative inventories decline more in bonds more heavily held by mutual funds, as suggested by the negative and highly significant coefficient of the interaction of $MF\ Share$ and $PostCrisis$. Controlling for time trends (which renders the $PostCrisis$ dummy redundant) does not affect our results (Column (2)). Our results change little when we control for potential time-varying impacts of bond characteristics due to the evolution of the pandemic (Column (3)).

Consistent with dealers' scaled-down inventories in bonds held more heavily by mutual funds during the post-crisis period, we find that transaction costs increase more in these bonds. We re-estimate model (5.1) by replacing $Cumu\ Inv\ Chg_{i,t}$ with $Cost_{i,t}$ using the same sample and report the regression results in the last three columns of Table 6, with $Cost_{i,t}$ defined in Equation (4.3). Column (4) shows that the coefficients of both $PostCrisis$ and the interaction of $MF\ Share$ and $PostCrisis$ are positive and highly significant, suggesting that it is more costly to trade municipal bonds in the post-crisis period, especially for bonds with higher mutual fund holding shares. Controlling for time trends and potential time varying effects of the pandemic again does not change our conclusion qualitatively (Columns (5) and (6)).

5.2 The Pricing implications of mutual fund fragility risks

The vulnerabilities of mutual funds to sudden withdrawals by investors and the associated market destabilizing impact substantially changed dealer behavior and liquidity conditions in the post-crisis muni market, especially for bonds with higher mutual fund exposures. Such large impacts are likely to carry pricing implications for the muni market. 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 in these bond may be scarce when needed the most.

In this subsection, we analyze whether fragility risks posed by mutual funds are priced in muni yield spreads in the post-crisis period. Figure 6 shows a persistent wedge between the yield spreads of bonds held by mutual funds and those that are not in the post-crisis period. To formally test this finding, we use the sample that spans the period from January 2 to July 17, but excludes March and April, and estimate the following panel regression:

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

where $Yield\ Spread_{i,t}$ refers to the tax-adjusted yield spread of bond i on day t. $Held\ by\ MF_{i,t}$

is a dummy that equals to one if the bond is held by mutual funds as of the most recent quarter-end. All other variables are defined as in Model (5.1). Standard errors are clustered at the bond and date levels.

Table 7 shows that the effect of mutual fund ownership on the pricing of municipal bonds changes after the crisis. In Column (1), the coefficient of $Held\ by\ MF$ is negative and highly significant, suggesting that prior to the recent crisis, bonds held by mutual funds exhibit lower yield spreads than other bonds.[19] However, during the post-crisis period, yield spreads of municipal bonds increase substantially more in bonds with mutual fund exposures, as implied by the positive signs of both the $PostCrisis$ dummy, and the interaction of $PostCrisis$ and $Held\ by\ MF$, both significant at the 1% levels. The results are also economically meaningful. While yield spreads for bonds not held by mutual funds increase by 112 basis points (bps), those for bonds with mutual fund holders increase by additional 34 bps. We find similar results when re-estimating Equation (5.2) by replacing $Held\ by\ MF$ with $MF\ Share$ (Column (2)). As shown in Figure 1, the Covid-19 pandemic continues to evolve during the post-crisis period as muni yield spreads remain elevated compared to their levels in January and February. Therefore, credit risks could also move differently depending on how the sources of revenues and the geographic locations of the municipalities for these bonds are affected by the evolution of the pandemic. We control for the general time trends (Column (3)) and potential time-varying differential impact of the pandemic on yield spreads of different groups of bonds (Column (4)). Our results remain robust.

5.3 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 attracted persistent inflows. Although the muni market faced

[19] This could potentially be attributed to mutual funds generally investing in more actively traded bonds that tend to be more liquid.

no immediate selloffs induced by mutual fund redemptions during this time period, the on-going nature of the pandemic is certainly consistent with the fear that investors could run again on mutual funds. To investigate the implications of mutual fund fragility for the muni markets, we examine multiple fragility sources stemming from mutual fund portfolio exposures, and study their impact on the pricing of mutual fund fragility risks.

Earlier, we showed that during the crisis period mutual funds' destabilizing effects on the muni market mainly result from massive redemptions by muni fund investors. 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. We estimate three measures of mutual fund fragility risks identified by Falato, Goldstein, and Hortaçsu (2020) as important factors in driving investment fund outflows during the Covid-19 crisis. These are a fund's exposure to sectors most hit by the Covid-19 pandemic, the average maturity of a fund's portfolios, and the average illiquidity levels of a fund's portfolios. We group munis into subsamples based on their investing funds' aforementioned fragility sources, and we test whether the effects of mutual fund holding shares on muni yield spreads during the post-crisis period intensify when a bond's mutual fund is more susceptible to investor runs.

First, we expect the impact of MF Share on the yield spread of a municipal bond should be stronger when its investing funds' portfolios are more exposed to the pandemic. We estimate a fund's Covid exposure by calculating the fund's share of muni holdings in sectors hit hardest by the pandemic, defined as transportation, health & nursing care, and leisure as of the most recent quarter-end. We calculate a bond's mutual fund holders' Covid exposure by taking the average of Covid exposures across its investing funds, weighted by the amount held by each fund. Finally, we use the median bond's mutual fund Covid exposure to divide our post-crisis sample (from May 1 to July 17, 2020, excluding bonds not held by mutual funds) into large and small groups. We test the following model on each subsample:

$$Yield\ Spread_{i,t} = \alpha + \beta \times MF\ Share_{i,t} + \gamma \times X_{i,t} + \sum \mu + \epsilon_{i,t}, \tag{5.3}$$

where $\sum \mu$ represent bond type, bond sector, bond state, date, bond type $\times$ date, bond sector $\times$ date, and bond state $\times$ date fixed effects. Results in Columns (1) and (2) in Table 8 support our hypothesis that the effect of $MF\ Share$ on yield spreads gets stronger when a bond's holding funds are more vulnerable. The coefficient of $MF\ Share$ is positive and highly significant in both subsamples, but its magnitude for the subsample of bonds with large Covid exposure is almost twice as big as that for the other subsample with small Covid exposure. The difference in the coefficient between the two subsamples is statistically significant at the 1% level.

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 start by estimating fund-level portfolio maturity by taking the average maturity of municipal bonds that a fund holds as of the most recent quarter-end, weighted by each bond's par amount held by the fund. We estimate a bond's mutual fund holders' portfolio maturity by averaging fund-level maturity measures across its investing funds, weighted by the par amount of the bond held by each fund. Finally, we split the post-crisis sample into two groups based on mutual fund holders' portfolio maturity of bonds, and re-estimate Equation (5.3) on each of the two subsamples. Consistent with our expectation, Columns (3) and (4) in Table 8 show that the coefficient of $MF\ Share$ is substantially larger when bonds' mutual fund holders' portfolio maturities are longer, with the difference significant at the 5% 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.

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, weighted by the par amount of each bond held by the fund.[20] We then calculate for each bond its average mutual fund holders' asset rating. Re-estimating Equation (5.3) on subsamples created based on whether the average portfolio rating of a bond's mutual fund holders is above the median, we again find stronger pricing effects of mutual fund holding shares in the subsample with lower mutual fund holders' portfolio ratings.

Together, these results show that bond holdings by mutual funds 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.

5.4 Testing for alternative explanations

A natural concern is that other mechanisms could also explain the positive association between mutual fund holding shares and muni yield spreads in the post-crisis period. For example, for issuers in the same state and belonging to the same sector, mutual funds might prefer to finance certain issuers over others. If these issuers favored by mutual funds also experience larger increase in yield spreads during the post-crisis period, then we would obtain results similar to those documented in Table 7.

To address the concern that unobservable issuer characteristics (that are favored by mutual funds) drive our results, we re-estimate Equation (5.2) replacing bond type, sector, and state fixed effects with issuer fixed effects. We also include date fixed effects to control for general time trends, and issuer-date fixed effects to control for potential time-varying impact of issuer-specific characteristics. These fixed effects essentially allow us to compare

[20] 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 the bonds that a fund hold.

yield spreads for bonds issued by the same issuer and traded on the day, and test whether those held more by mutual funds exhibit higher yield spreads.

Column (1) of Table 9 shows that controlling for these issuer-related fixed effects does not change our conclusions. Although our sample size drops notably compared to Table 7, the coefficient of the interaction of *MF share* and *PostCrisis* remains positive and highly significant. Importantly, its magnitude continues to be substantially larger than that of *MF share*, leading to a positive relation between yield spread and mutual fund share during the post-crisis period. Indeed, when we re-estimate the model without the interaction term separately for the two sub-periods (i.e, one pre-crisis period that covers January and February, and one post-crisis period since May), the sign of the coefficient on *MF Share* flips when moving from the pre-crisis sample to the post-crisis sample (Columns (2) and (3)). The positive and highly significant *MF Share* during the post-crisis period suggests that even when comparing among bonds from the same issuer traded on the same day, those held more heavily by mutual funds tend to exhibit higher yield spreads.

We also find that controlling for unobservable issuer characteristics does not change our conclusions regarding the impact of mutual fund holders' fragility on bond pricing. As shown in Table 10, when a bond's mutual fund holders are more vulnerable to potential investor runs (i.e., when they are more exposed to the pandemic, or holding bonds with longer maturities or lower credit ratings), the effects of their holding share on the bond's yield spreads are significantly stronger (both economically and statistically) than when they are more resilient. In fact, the coefficient of *MF Share* is only weakly or not significant when a bond's mutual fund holders exhibit low fragility.

Another alternative explanation for our finding that the sign of *MF Share* flips from negative to positive after the crisis 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. For example, 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.[21] 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.[22] 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 (5.2) and present our results 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 Table 7, and it is robust to various model specifications. This finding does not support the argument that our results are driven by mutual funds reaching for yields in the post-crisis period, and it reinforces our hypothesis that mutual fund fragility risks are priced in muni yield spreads.

6 Conclusion

The Covid-19 crisis provides an opportunity to examine the effects of large mutual fund outflows on the muni markets. 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 heavily, and their yield spreads widen significantly more, especially when their holding funds suffer stronger outflows.

[21]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)).

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

Such destabilizing effects of mutual fund outflows seem to have been amplified by dealers' pulling back from their liquidity provisions. We demonstrate how dealers shift from buying to selling in bonds that are likely facing flow induced selling pressures, further exacerbating liquidity conditions in these bonds. More importantly, the fragility risks posed by mutual funds seem to have lasting effects on the municipal bond market. Following the stabilization of mutual fund flows, muni dealer inventories in bonds held by mutual funds continue to drift downward, although 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 also 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.

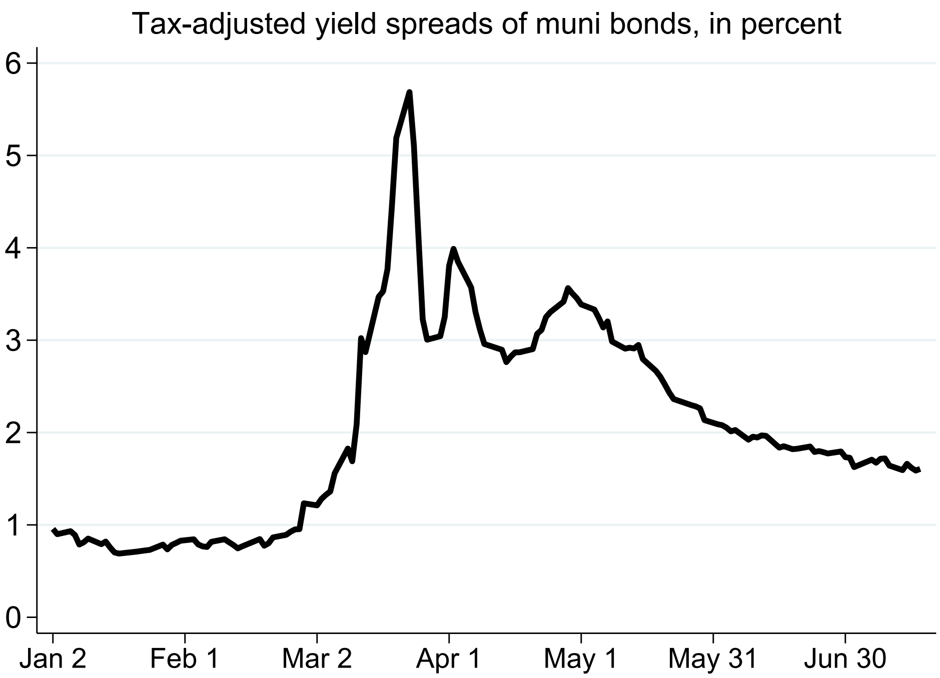
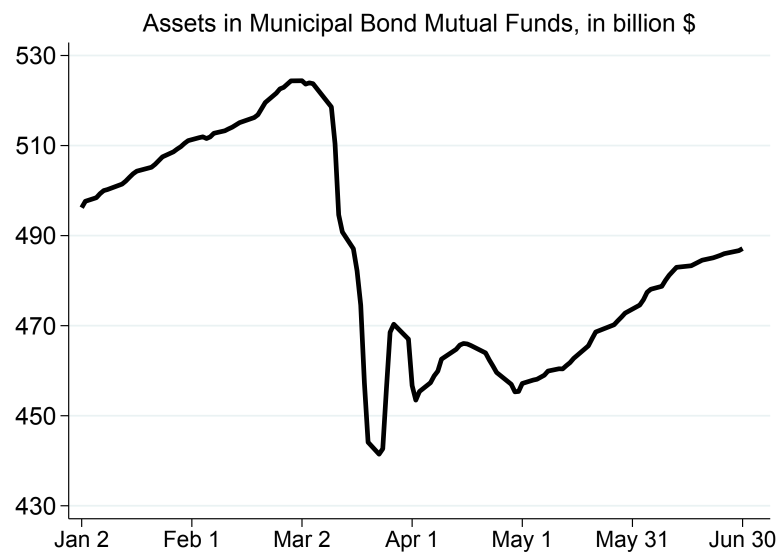


Figure 2: **AUMs and flows in municipal bond mutual funds**

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.



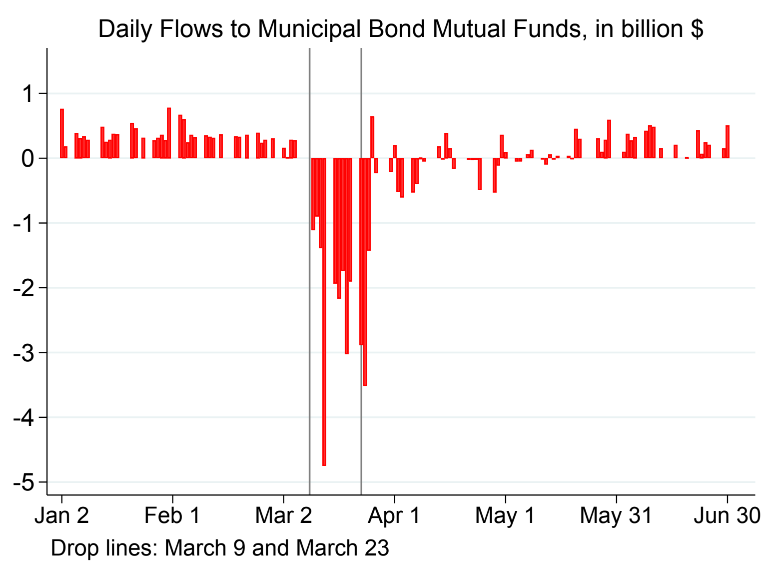
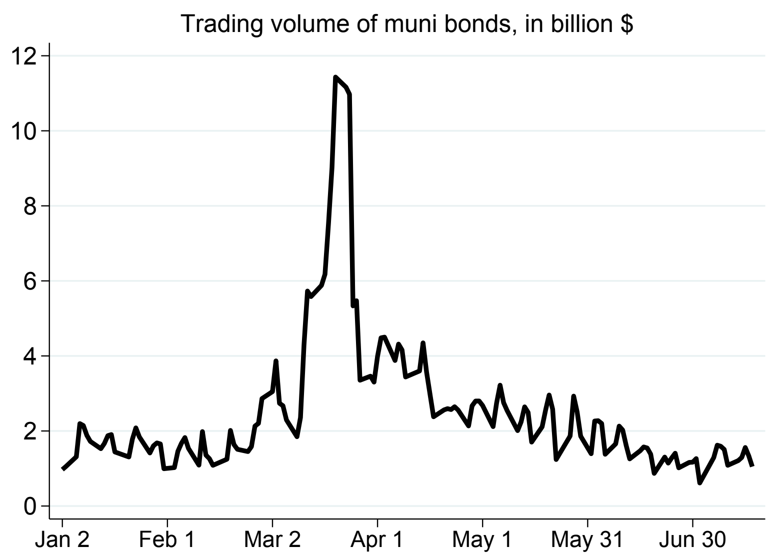


Figure 3: **Municipal bond trading volume in 2020**

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.



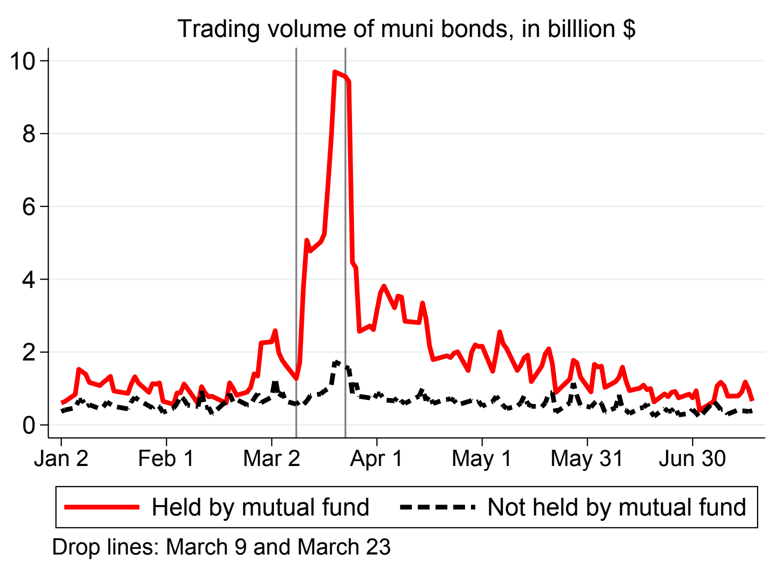


Figure 4: **Municipal bond dealer inventory in 2020: by mutual fund ownership**

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.

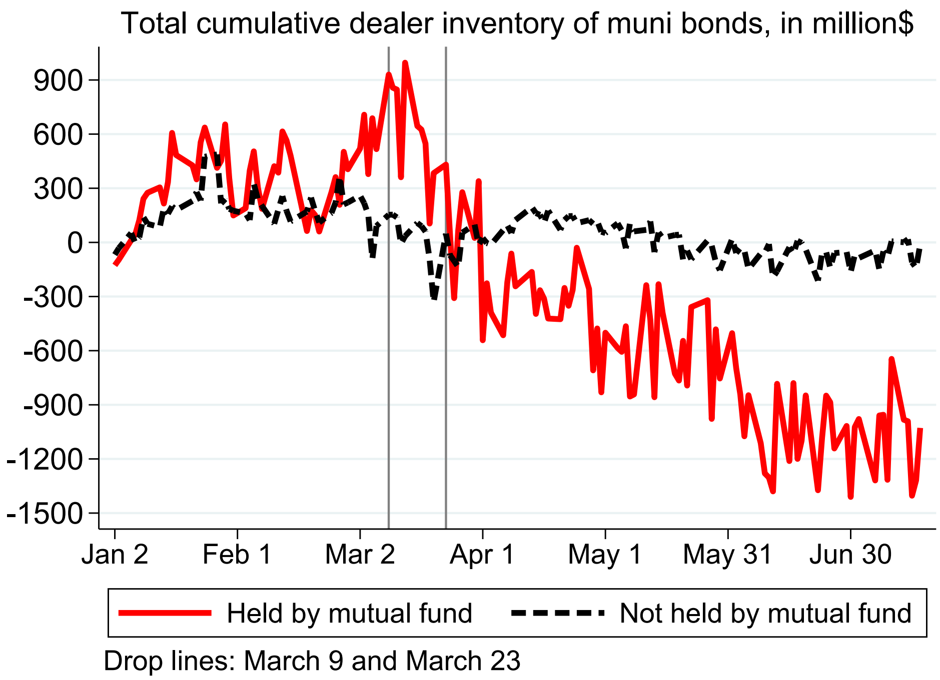


Figure 5: **Municipal bond transaction cost in 2020: by mutual fund ownership**

This figure shows the daily time series of average transaction costs for municipal bonds by their mutual fund ownership, in percent. CUSIP-level mutual fund holding information is obtained from eMAXX, as of each quarter-end. Transaction costs are based on the trading data of municipal bonds from MSRB. 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.

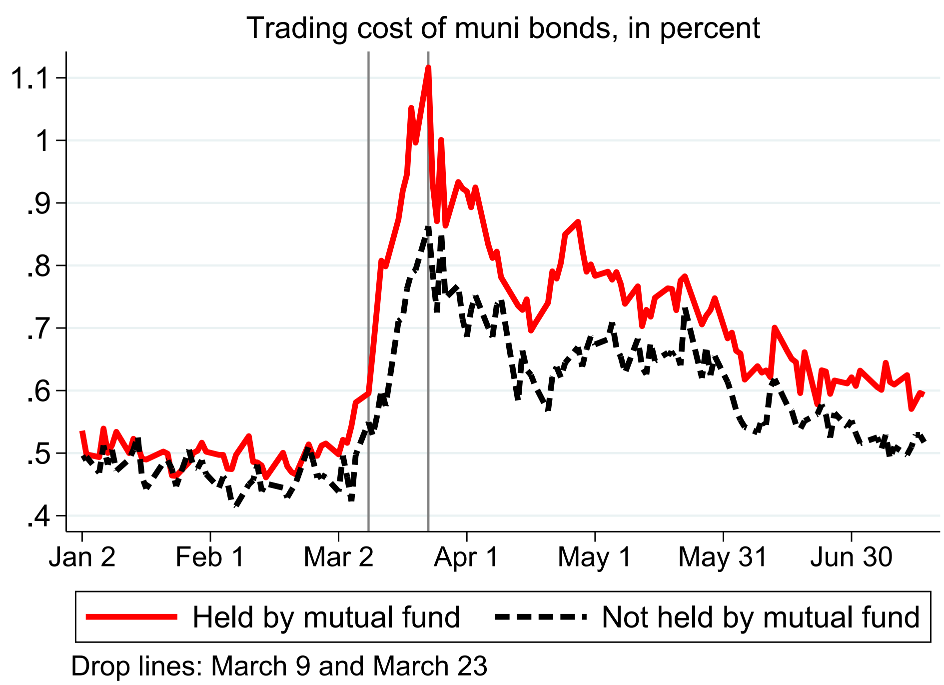


Figure 6: **Municipal bond yield spreads in 2020: by mutual fund ownership**

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.

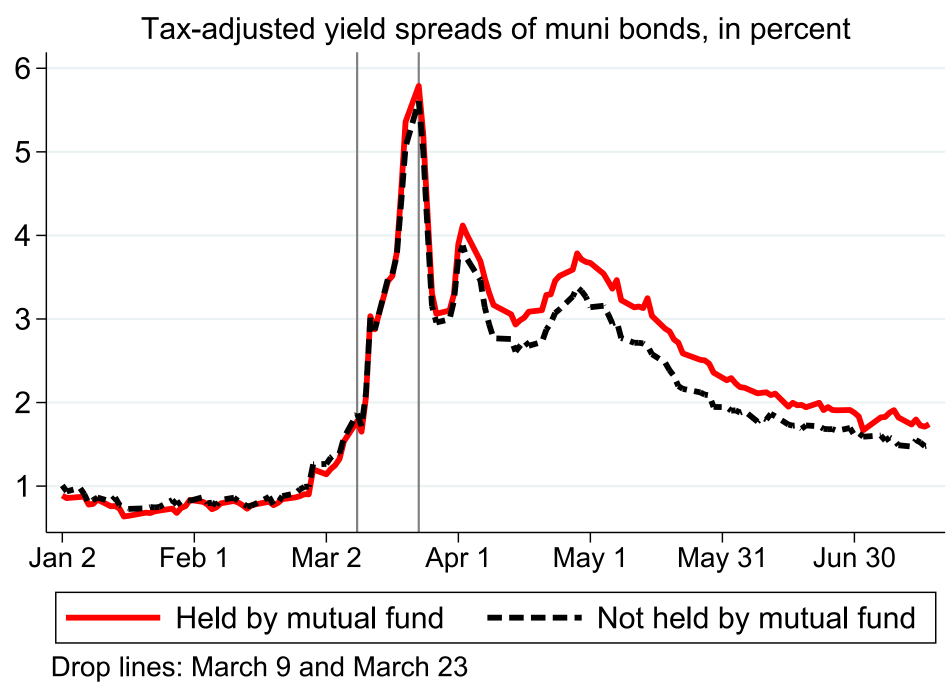


Table 1: **Summary statistics for pre-crisis municipal bonds**

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 (%)	32,047	0.85	0.54	1.03	75,439	0.87	0.60	0.94
Rating	29,081	3.85	3	2.31	70,576	3.03	3	1.68
Coupon	32,050	4.82	5	0.56	75,447	4.12	4	0.96
Age (in years)	32,050	4.47	3.88	3.02	75,447	4.44	3.99	2.71
Year to maturity	32,050	10.49	8.75	7.43	75,447	8.36	7.09	5.86
Trading volume ($)	32,050	321,711	50,000	1,566,792	75,447	139,925	33,333	1,140,834
Amount outstanding ($)	32,050	25,700,000	13,600,000	42,000,000	75,447	4,132,168	2,175,000	6,300,318
MF share	32,050	0.32	0.27	0.25	75,447	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 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. 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)
Held by MF × Crisis	0.290***	0.277***		
	(7.11)	(7.12)		
MF share × Crisis			0.915***	0.921***
			(8.02)	(8.22)
Held by MF	0.061**	0.069**		
	(2.19)	(2.66)		
MF share			0.582***	0.576***
			(9.62)	(9.58)
Rating	-0.007	-0.007	-0.023***	-0.024***
	(-1.38)	(-1.51)	(-4.18)	(-4.27)
Coupon	0.072***	0.073***	0.050***	0.051***
	(6.80)	(6.91)	(5.08)	(5.19)
Age	-0.033***	-0.032***	-0.029***	-0.029***
	(-10.33)	(-10.19)	(-8.53)	(-8.42)
Year to maturity	0.002	0.002	-0.002	-0.002
	(0.97)	(1.02)	(-1.60)	(-1.53)
log(Amount outstanding)	0.146***	0.146***	0.136***	0.137***
	(12.60)	(12.76)	(13.53)	(13.76)
Bond type FE	Yes	Yes	Yes	Yes
Bond sector FE	Yes	Yes	Yes	Yes
Bond state FE	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Bond type×Date FE		Yes		Yes
Bond sector×Date FE		Yes		Yes
Bond state×Date FE		Yes		Yes
Adj. R^2	0.059	0.062	0.076	0.079
N of obs.	197045	197043	197045	197043

Table 3: **Mutual fund ownership and dealer intermediation during crisis**

The dependent variable for Columns (1)–(2) is daily dealer net purchase (i.e., net inventory change) of individual municipal bond, in million dollars. The dependent variable for Columns (3)–(4) is transaction cost of municipal bonds, in percent. 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. *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 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. 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.

	Dealer net purchase		**Transaction cost**	
	(1)	(2)	(3)	(4)
MF share × Crisis	-0.062***	-0.062***	0.119***	0.064**
	(-3.41)	(-3.42)	(4.46)	(2.54)
MF share	0.035***	0.035***	-0.278***	-0.242***
	(3.47)	(3.60)	(-6.47)	(-6.46)
Rating	0.003***	0.003***	0.034***	0.032***
	(5.72)	(5.87)	(14.40)	(14.04)
Coupon	0.003***	0.003***	-0.054***	-0.054***
	(2.91)	(2.98)	(-13.63)	(-13.56)
Age	0.001	0.001	-0.035***	-0.036***
	(0.87)	(0.93)	(-9.57)	(-9.59)
Year to maturity	-0.000	-0.000	0.019***	0.019***
	(-0.76)	(-0.74)	(9.99)	(9.87)
log(Amount outstanding)	-0.002**	-0.002**	0.081***	0.082***
	(-2.58)	(-2.44)	(5.89)	(5.89)
log(Trading volume)	-0.007	-0.007	-0.055***	-0.057***
	(-1.22)	(-1.25)	(-8.42)	(-8.70)
Bond type FE	Yes	Yes	Yes	Yes
Bond sector FE	Yes	Yes	Yes	Yes
Bond state FE	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes
Bond type×Date FE		Yes		Yes
Bond sector×Date FE		Yes		Yes
Bond state×Date FE		Yes		Yes
Adj. R^2	0.006	0.007	0.129	0.130
N of obs.	197045	197043	88498	88489

Table 4: **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. $3day\ outflow$ is bond-level flow measure, calculated as the average of the bond's mutual fund holders' cumulative percentage outflows over the most recent three business days (i.e., from date $t-2$ to date t), weighted by each fund's holding amount of that bond. 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. 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)
MF share	1.551***	1.113***	1.106***
	(14.36)	(10.26)	(10.52)
MF share × 3-day outflow		0.505***	0.507***
		(10.35)	(10.12)
3-day outflow		-0.015	-0.018
		(-0.66)	(-0.75)
Rating	-0.051***	-0.060***	-0.059***
	(-3.40)	(-4.18)	(-4.01)
Coupon	-0.049	-0.049	-0.043
	(-1.09)	(-1.06)	(-0.91)
Age	-0.004	-0.004	-0.004
	(-0.58)	(-0.63)	(-0.66)
Year to maturity	0.012***	0.011***	0.011***
	(3.70)	(3.29)	(3.31)
log(Amount outstanding)	0.280***	0.276***	0.276***
	(11.89)	(12.23)	(12.31)
Bond type FE	Yes	Yes	Yes
Bond sector FE	Yes	Yes	Yes
Bond state FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Bond type×Date FE			Yes
Bond sector×Date FE			Yes
Bond state×Date FE			Yes
Adj. R^2	0.092	0.101	0.100
N of obs.	27120	27120	27102

Table 5: **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. $3day\ outflow$ is bond-level flow measure, calculated as the average of the bond's mutual fund holders' cumulative percentage outflows over the most recent three business days (i.e., from date $t-2$ to date t), weighted by each fund's holding amount of that bond. 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. 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)
MF share	0.272***	0.163***	0.189***
	(6.88)	(3.47)	(4.18)
MF share × 3-day outflow		0.128**	0.102*
		(2.77)	(2.22)
3-day outflow		0.006	0.017
		(0.36)	(0.90)
Rating	0.217***	0.215***	0.213***
	(26.93)	(25.82)	(26.35)
Coupon	-0.149**	-0.149**	-0.148**
	(-2.69)	(-2.65)	(-2.60)
Age	-0.030**	-0.030**	-0.030**
	(-3.05)	(-3.06)	(-3.09)
Year to maturity	-0.011	-0.011	-0.011
	(-1.49)	(-1.53)	(-1.57)
log(Amount outstanding)	0.002	0.001	-0.002
	(0.12)	(0.11)	(-0.18)
log(Trading volume)	-0.142***	-0.145***	-0.143***
	(-14.29)	(-15.04)	(-16.06)
Bond type FE	Yes	Yes	Yes
Bond sector FE	Yes	Yes	Yes
Bond state FE	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Bond type×Date FE			Yes
Bond sector×Date FE			Yes
Bond state×Date FE			Yes
Adj. R^2	0.539	0.540	0.547
N of obs.	27117	27117	27099

Table 6: **The aftermath: dealer inventory and transaction costs**

The dependent variable for Columns (1)–(3) is cumulative dealer inventory of individual municipal bond since January 2, 2020, in million dollars. The dependent variable for Columns (4)–(6) is transaction cost of individual municipal bond, in percent. 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. *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. Characteristics controls include bond rating, coupon, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. 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. 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.

	Cumulative dealer inventory			**Transaction cost**		
	(1)	(2)	(3)	(4)	(5)	(6)
Post-crisis	-0.064***			0.134***		
	(-4.41)			(11.28)		
MF share×Post-crisis	-0.859***	-0.860***	-0.873***	0.129***	0.126***	0.055***
	(-5.57)	(-5.58)	(-5.83)	(9.11)	(8.97)	(3.73)
MF share	0.376***	0.377***	0.383***	-0.147***	-0.146***	-0.100***
	(4.24)	(4.24)	(4.32)	(-11.41)	(-11.36)	(-8.57)
Characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes
Bond type FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond state FE	Yes	Yes	Yes	Yes	Yes	Yes
Date FE		Yes	Yes		Yes	Yes
Bond type×Date FE			Yes			Yes
Bond sector×Date FE			Yes			Yes
Bond state×Date FE			Yes			Yes
Adj. R^2	0.010	0.010	0.007	0.176	0.184	0.188
N of obs.	702468	702468	702451	322216	322216	322172

Table 7: **The aftermath of mutual fund fire sales: yield spreads**

The dependent variable is tax-adjusted yield spread of individual municipal bond, in percent. 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. Characteristics controls include bond rating, coupon, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. 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. 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)
Post-crisis	1.117***	1.121***		
	(14.94)	(14.69)		
Held by MF × Post-crisis	0.342***			
	(19.32)			
MF share × Post-crisis		1.192***	1.177***	0.728***
		(23.73)	(24.02)	(20.11)
Held by MF	-0.193***			
	(-10.84)			
MF share		-0.513***	-0.503***	-0.235***
		(-10.12)	(-10.10)	(-7.81)
Characteristics controls	Yes	Yes	Yes	Yes
Bond type FE	Yes	Yes	Yes	Yes
Bond sector FE	Yes	Yes	Yes	Yes
Bond state FE	Yes	Yes	Yes	Yes
Date FE			Yes	Yes
Bond type×Date FE				Yes
Bond sector×Date FE				Yes
Bond state×Date FE				Yes
Adj. R^2	0.515	0.519	0.598	0.625
N of obs.	702372	702372	702372	702355

Table 8: **Fragility sources and the pricing of mutual fund fragility risks**

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 May 1 to July 17, 2020 (i.e., the post-crisis period). 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. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative its outstanding amount. Bond characteristics controls include: rating, coupon, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. 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. 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**	
	(1) **Large**	(2) **Small**	(3) **Long**	(4) **Short**	(5) **Low**	(6) **High**
MF share	0.400***	0.208***	0.439***	0.276***	0.466***	0.123***
	(7.18)	(5.17)	(7.56)	(7.54)	(7.97)	(3.16)
Characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond type FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond sector FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond state FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond type×Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond sector×Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Bond state×Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.613	0.591	0.600	0.638	0.602	0.605
N of obs.	92182	96555	92464	96249	91981	96738

Table 9: **Test alternative explanation: unobservable issuer characteristics**

The dependent variable is tax-adjusted yield spread of municipal bonds, in percent. The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades). The sample period for the Columns (1) is Jan 2 to Jul 17, 2020 (excluding March and April), the sample period for the Columns (2) is Jan 2 to Feb 28, 2020 (pre-crisis), and the sample period for Columns (3) is May 1 to Jul 17, 2020 (post-crisis). *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 issuer is identified by the first 6 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) **Full Sample**	(2) **Pre-Crisis**	(3) **Post-Crisis**
MF share × Post-crisis	0.224***		
	(10.36)		
MF share	-0.074***	-0.049***	0.116***
	(-4.79)	(-3.74)	(5.30)
Characteristics controls	Yes	Yes	Yes
Date FE	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes
Issuer×Date FE	Yes	Yes	Yes
Adj. R^2	0.767	0.550	0.739
N of obs.	531024	216771	314253

Table 10: **Fragility sources and the pricing of mutual fund fragility risks: controlling for issuer fixed effects**

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 May 1 to July 17, 2020 (i.e., the post-crisis period). 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. $MF\ share$ is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative its outstanding amount. Bond characteristics controls include: rating, coupon, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. Bond issuer is identified by the first 6 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)					
	MF holders' Covid exposure		**MF holders' portfolio maturity**		**MF holders' portfolio rating**	
	(1) **Large**	(2) **Small**	(3) **Long**	(4) **Short**	(5) **Low**	(6) **High**
MF share	0.253***	0.055*	0.312***	-0.009	0.275***	0.057*
	(4.62)	(1.75)	(5.73)	(-0.34)	(4.81)	(1.87)
Characteristics controls	Yes	Yes	Yes	Yes	Yes	Yes
Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer×Date FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.756	0.762	0.748	0.820	0.740	0.775
N of obs.	67602	73161	67497	72249	66733	74248

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 focus on muni bonds whose total holding amount by mutual funds is unchanged from the end of 2020:Q1 to the end of 2020:Q2 and exclude bonds that are not held by 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. Characteristics controls include bond rating, coupon, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. 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 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)
Post-crisis	1.251***		
	(14.19)		
MF share × Post-crisis	1.105***	0.775***	0.314***
	(19.69)	(16.76)	(9.24)
MF share	-0.376***	-0.206***	-0.072***
	(-7.48)	(-5.92)	(-3.63)
Characteristics controls	Yes	Yes	Yes
Bond type FE	Yes	Yes	
Bond sector FE	Yes	Yes	
Bond state FE	Yes	Yes	
Date FE		Yes	Yes
Bond type×Date FE		Yes	
Bond sector×Date FE		Yes	
Bond state×Date FE		Yes	
Issuer FE			Yes
Issuer×Date FE			Yes
Adj. R^2	0.569	0.669	0.795
N of obs.	181162	181046	133301