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

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Abstract

Against the backdrop of COVID-19, we study how the interactions of mutual funds and dealers introduce fragility to the municipal bond market and induce lasting market impacts. During the crisis, trading surges while dealers' liquidity provision plunges for mutual-fund-held bonds, leading to greater price depressions in these bonds. Importantly, the crisis reshapes the market's perceptions of mutual fund fragility risks, with the aftermath-yield spreads widening significantly more for bonds with greater mutual fund exposures. Such post-crisis pricing effects reflect dealers' continued reluctance to provide liquidity for mutual-fund-held bonds and they are stronger for bonds whose mutual fund holders are more susceptible to investor runs.

Keywords: Municipal bonds, mutual fund fragility, dealer, liquidity, pricing, COVID-19

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

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1 Introduction

Over the past decade, open-end mutual funds have become prominent players in fixed income markets. This increasing significance has raised substantial fragility concerns: Because these funds finance illiquid fixed income assets through liquid liabilities, their liquidity transformation could incentivize investors to redeem ahead of others in the face of a negative shock, amplifying withdrawals and aggravating liquidations of the underlying assets.[1] Equally concerning, regulatory reforms introduced following the financial crisis might have adversely impacted liquidity provision in fixed-income markets. By tightening capital and liquidity requirements, these regulations likely limit dealers' market making capacities and discourage their risk taking, both of which are particularly valuable during times of stress.[2]

The COVID-19 pandemic ushered in the first systemic stress event featuring large-scale runs on mutual funds while dealers faced stricter regulatory constraints. What do we learn from this episode regarding the impact of mutual fund fragility risks on the underlying markets during times of stress? What role is played by dealers in transmitting such fragility risks? Equally important, does this crisis episode reshape the market's perceptions of mutual fund fragility risks and, if so, how? Do such risks carry lasting effects on the underlying markets? In this paper, we address these questions by studying the interactions of mutual funds and dealers and linking them to dynamics in the municipal bond (muni) market during and after the COVID-19 crisis.

The $4 trillion muni market is particularly well-suited for our study: the market is characterized by low liquidity and high reliance on dealer intermediation, and there are few means to hedge price movements. Retail investors still dominate the muni market, but open-

[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.

[2] See Bao, O'Hara, and Zhou (2018), Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018), and Dick-Nielsen and Rossi (2019) for discussion.

end mutual funds have quickly grown to be the largest institutional investors, holding about 20 percent of outstanding munis. Importantly, the destabilizing runs on mutual funds during the COVID-19 crisis posed a major shock to the muni market, as muni funds had attracted persistent inflows for more than a year prior to the pandemic. The unprecedented outflows from mutual funds during the COVID-19 crisis make the muni market an ideal laboratory to study potential lasting effects of mutual fund fragility risks.

The key identification challenge is how to disentangle the effects of mutual fund fragility risks from (i) the broader economic impacts arising directly from the pandemic and (ii) the (potentially time-varying) effects of bond characteristics. Certainly, the pandemic wreaked havoc on the finances of municipalities, creating both higher risk and uncertainty for municipal bond holders and issuers. To differentiate between such broad pandemic-driven effects and the effects specific to mutual fund fragility, we exploit the fact that municipal bond funds hold positions in only about one quarter of bond issues, with the remaining issues held by other investors. This dichotomization allows us to control for the broader impacts of the pandemic on the muni market while extricating the specific effects due to mutual fund fire sales and their aftermath. As we show, the behavior of bonds held by mutual funds, while similar to that of bonds not held by funds before the crisis, diverges both during and after the crisis.

Moreover, we need to ensure that bonds held by mutual funds and those that are not are comparable, as bond characteristics could potentially drive our results. We tackle this challenge by controlling for time-varying impacts of various bond characteristics (including bond size, age, time to maturity, coupon rate, credit rating, bond type, issuer sector, and issuer location). In the strictest specification, we also include issuer-time fixed effects, which essentially allows us to test the effects of mutual fund fragility risks by comparing similar bonds from the same issuer traded in the same time period.

We start by analyzing how mutual fund fragility risks materialized during the COVID-19 crisis and how these risks were amplified by dealers. In the two weeks between March 9 and

March 23, 2020, investors redeemed mutual fund shares en masse, leading to massive outflows from muni funds and a drop of 16% of their total assets. Unlike corporate bond mutual funds which can meet redemptions with their cash buffers (Chernenko and Sunderam, 2016) or the selling of liquid Treasury holdings (Ma, Xiao, and Zeng, 2020), municipal mutual funds hold little cash (on average 2% of their assets prior to the COVID-19 crisis) and almost no Treasury bonds. Such a unique asset composition renders muni funds particularly vulnerable to liquidity shortfalls, likely leading to excessive trading in the face of large outflows. Indeed, municipal bond trading volume increased six-fold between late February and March 23, which we show was almost entirely driven by the trading of bonds held by mutual funds.

How do dealers respond to mutual fund selloffs? Ultimately, whether mutual fund fire sales threaten the stability of the muni market relies on dealers' liquidity provisions. Dealers' willingness to intermediate trading, however, is likely to decline in bonds facing larger mutual fund redemption risks. Not only is it challenging for muni dealers to locate potential buyers for mutual funds' bulk sales in a retail dominated market, but also mutual fund fire sales can subject dealers to losses if dealers keep mutual-fund-held bonds in their inventories.

We demonstrate the critical role that dealers play in transmitting mutual fund fragility risks to the underlying market. Amidst the surge in demand for liquidity at the height of the crisis, dealers actually shift from buying to selling, especially in bonds with mutual fund ownership. Consistent with mutual funds' excessive selling and dealers' pulling back from liquidity provision in munis exposed to mutual fund fire sales, we find that mutual-fund-held bonds experience larger crisis-time price depression, especially when their mutual fund holders suffer larger redemptions.

Our analysis illustrates how mutual fund redemptions destabilize the muni market during the COVID-19 crisis and highlights the dealers' role in transmitting such fragility risks. But given the unprecedented nature of this event in the muni market, has this crisis episode led the market to reassess potential fragility risks posed by mutual funds? Is this change of perceptions reflected in post-crisis market dynamics? Using a difference-in-difference approach, we analyze how the impact of mutual fund exposure on muni yield spreads changes from the pre-crisis period (five months before March 2020) to the post-crisis period (five months since May 2020).[3] Our results provide strong evidence that the muni market continues to be concerned with the potential destabilizing effects associated with mutual funds, even after the normalization of fund flows. Specifically, compared to a bond not held by mutual funds, a bond with average mutual fund ownership of 33% experiences an additional increase of 9 basis points in its post-crisis yield spread (equivalent to 9% of median-level yield spread), after controlling for time-varying effects of bond and issuer characteristics. Importantly, such a persistent wedge between the yield spreads of bonds held by mutual funds and those that are not is not explained by a slow recovery from crisis-time price depressions. Rather, it is a premium reflecting *potential* mutual fund fire sales incorporated in bond pricing (even for bonds that were not traded at all during the COVID-19 crisis).

We explore two potential mechanisms for the post-crisis pricing effects: a liquidity channel and a run risk channel. First, wider post-crisis yield spreads of munis with greater mutual fund exposures could reflect greater liquidity deterioration of these bonds. If the COVID-19 crisis changes dealers' perceptions of potential risks posed by mutual fund runs, their reluctance to take inventory of mutual-fund-held munis is likely to continue even after the crisis, especially when the market operates without the Federal Reserve acting as market maker of last resort as in the corporate bond market (O'Hara and Zhou, 2020a). Consistent with this liquidity channel, we find that in the aftermath of the muni crisis, dealers continue to reduce their inventories, significantly more in bonds held more heavily by mutual funds. In addition, post-crisis liquidity deteriorates more in such bonds, particularly for the most actively traded issues.

Second, wider yield spreads of munis with greater mutual fund exposures could also reflect higher run risks. If market participants learn from the crisis episode about the destabilizing effects caused by mutual fund runs, they should require higher compensation for holding

[3] We exclude March and April of 2020 from the sample to minimize the direct and immediate impact of mutual fund runs and government interventions.

bonds whose mutual fund owners are more susceptible to runs. To explore this run risk channel, we identify fund-level factors that could drive investor outflows in times of stress and link those latent run-risk sources to the pricing of individual bonds. Specifically, we calculate four measures of mutual fund fragility risks based on funds' portfolio holdings: exposure to sectors most hit by the pandemic, average maturity, average illiquidity levels, and cash holdings.[4] We then group bonds held by mutual funds into subsamples based on the average of their holding funds' aforementioned fragility sources, and use a triple-difference approach to test whether the post-crisis effects of mutual fund ownerships on muni yield spreads intensify when a bond's holding funds are more susceptible to investor runs. Our results show that the pricing effects during the post-crisis period are significantly more pronounced when the assets of a bond's mutual fund holders are more exposed to the pandemic, have longer maturity, are less liquid, or contain less cash.

Our paper provides several new insights to the literature. First, our paper is the first to study long-lasting effects of mutual fund fragility on the underlying fixed income markets. In particular, we show that the destabilizing effects of mutual funds during a major crisis can change market perceptions of mutual fund fragility risks in the aftermath, which are reflected in bond prices long after the normalization of fund flows. The existing literature on market effects of mutual fund fragility largely focuses on immediate impacts of investor redemptions, studying whether large outflows from mutual funds lead to asset fire sales and destabilize the underlying markets (see, in the context of corporate bond market, Chernenko and Sunderam, 2016; Jiang, Li, and Wang, 2020; Choi, Hoseinzade, Shin, and Tehranian, 2020; Haddad, Moreira, and Muir, 2020; and Ma, Xiao, and Zeng, 2020).[5] While our crisis-time

[4] The first three factors are identified by Falato, Goldstein, and Hortaçsu (2020) as factors driving fixed-income fund outflows during the COVID-19 crisis. The fourth measure, fund's cash holdings, is shown to be actively managed by fund managers in anticipation of potential investor outflows by Chernenko and Sunderam (2016, 2020).

[5] Using a sample that ends before the COVID-19 crisis, Anand, Jotikasthira, and Venkataraman (2021) show that a subset of mutual funds increase their corporate bond holdings during times of large customer selling. A related literature studies how liquidity transformation leads to amplified redemptions in fixed income mutual funds. Research by Chen, Goldstein, and Jiang (2010) and Zeng (2017) develop the theoretical basis for such fragility concern, which is empirically studied in Goldstein, Jiang, and Ng (2017) and Falato, Goldstein, and Hortaçsu (2020), among others. Relatedly, Chernenko and Sunderam (2020) and Falato,

analysis confirms prior findings (albeit in the context of a different market), our aftermath analysis shows that not only the actual occurrence of mutual fund runs, but also changes in expectations about potential mutual fund runs can introduce lasting pricing effects as well. The finding of such a post-crisis "fire sale premium" and a careful examination of its mechanisms differentiates our paper from existing studies on mutual fund fragility.

Second, we highlight the interplay between mutual funds and dealers in fixed-income markets, showing that the lack of dealer intermediation can exacerbate illiquidity and amplify fragility risks posed by mutual funds. Extensive studies have been conducted on the determinants of dealer behaviors and their effects on the underlying markets.[6] For example, Breckenfelder and Ivashina (2021) show that dealer balance sheet constraints affect mutual fund valuations and corporate bond liquidity. For the muni market, several papers have studied how price transparency, market power, and trading networks affect dealer behaviors, and ultimately transaction costs and price discovery (see, for examples, Harris and Piwowar, 2006; Green, Hollifield, and Schürhoff, 2007a,b; Green, Li, and Schürhoff, 2010; Schultz, 2012; and Li and Schürhoff, 2019). We contribution to this large literature by analyzing how dealers' liquidity provisions are affected by their perceptions of fragility risks posed by mutual funds, and how their pulling back from mutual-fund-held bonds can affect both liquidity and pricing of these bonds.

Lastly, our study sheds new light on the effectiveness of various liquidity and credit facilities that the Federal Reserve launched to combat the impact of the COVID-19 pandemic

Hortacsu, Li, and Shin (2020) study potential spillover effects of flow induced fire sales. Jiang, Li, Sun, and Wang (2021) show that the level of mutual fud liquidity transformation can serve as a latent factor in predicting individual bond price movements

[6]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); Bao, O'Hara, and Zhou (2018); Bessembinder, Jacobsen, Maxwell, and Venkataraman (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).

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

This paper is organized as follows. Section 2 gives a brief overview of municipal bond market and its developments during the COVID-19 crisis, discusses the data in the paper, and provides summary information of our sample. Section 3 develops six main hypotheses that guide our empirical analysis. Section 4 analyzes the crisis period, examining the impacts of mutual fund outflows on trading volume, dealer inventory changes, and yield spreads in the underlying muni market. Section 5 examines whether fragility risks are priced in municipal bond yield spreads in the post-crisis period, explores two potential mechanisms for the post-crisis pricing effects, and conducts additional analyses to rule out alternative explanations for our findings. Section 6 is a conclusion.

2 Background, data, and summary statistics

In this section, we provide a brief overview of the municipal bond market and its developments during the COVID-19 crisis. We then discuss data sources and sample construction. Finally, we provide summary information of municipal bond characteristics in our sample.

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

2.1 Institutional background

The U.S. municipal bond market plays an important role in financing states and municipalities. The market is highly fragmented 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. A particular problem for dealers is that unlike corporate bonds, municipal bonds are hard to hedge.[8] Muni derivatives markets are small, making it difficult to hedge in any size, and large bid-ask spreads compound the problem. These market characteristics could render the municipal bond market fragile in times of stress, when dealers' ability to intermediate trades and absorb shocks is particularly valuable.

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

The muni market experienced severe strains in March 2020 due to the coronavirus pandemic, during which yield spreads of municipal bonds soared (Figure A.1) and municipal

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

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

bond mutual funds suffered unprecedented investor redemptions (Figure 1). 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 the Primary Dealer Credit Facility (PDCF) on March 20, 2020, 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 announced the establishment of the Municipal Liquidity Facility (MLF) and on April 27, the Federal Reserve announced an expansion of the scope of MLF.[10] Shortly following the Federal Reserve interventions in March, muni market conditions started to improve. Muni yield spreads dropped substantially, and muni mutual fund outflows ceased.

2.2 Data sources

Our study uses data from multiple sources. For the one-year period October 1, 2019 to September 30, 2020, we obtain transaction-level data on secondary market trading between dealers and customers from Municipal Securities Rulemaking Board (MSRB). 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 the Mergent Municipal Bond Securities Database, including bond rating, amount outstanding, coupon, issuer name, bond sector, bond type, whether exempted from federal or state tax, whether insured, etc. After merging the MSRB data with municipal bond char-

[10] The original MLF can purchase up to $500 billion of short term notes directly from U.S. states (including the District of Columbia), U.S. counties with a population of at least two million residents, and U.S. cities with a population of at least one million residents. The expansion lowered population thresholds to 500,000 residents for counties and 250,000 residents for cities. Only two issuers, State of Illinois and Metropolitan Transportation Authority (NY), issued municipal notes via MLF. The MLF ceased operations on December 31, 2020.

acteristics, 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.[11] Consistent with the illiquidity of the municipal bond markets, although over 1 million municipal bonds were outstanding by the end of 2019, only 252,607 eligible bonds traded during our sample period and hence are included in our analysis. We also collect federal tax rates and state tax rates for the tax years of 2019 and 2020, and follow Schwert (2017) in calculating tax-adjusted municipal bond yields.[12]

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.[13] Due to the vast number of municipal bonds, the holdings of a specific bond tend to concentrate among a small set of mutual funds. 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 252,607 bonds trading during our sample period, about one quarter of them have some mutual fund holders, with the rest held exclusively by other institutions and retail investors. 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.

2.3 Summary statistics of bond characteristics

We compare 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 the five months prior to the start of the crisis (i.e., October 1, 2019 to February 28, 2020), with bonds held by mutual funds accounting for about 25% of this

[11] 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.

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

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

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 bond issues and bonds with higher daily trading volumes. The mean total par amount outstanding and the mean daily trading volume for bonds invested in by mutual funds are $23 million and $326 thousand respectively, substantially larger than those for other bonds, which are only $3.5 million and $136 thousand. In addition, compared to other bonds, those held by mutual funds are rated slightly lower and carry a somewhat higher coupon rate.[14] There is no difference in age between the two groups of municipal bonds, while the mean number of years to maturity is about 10 years for mutual fund invested bonds, higher than that for other bonds (8 years). We control for all these bond characteristics when testing for the effects of mutual fund fragility risks.

We also consider additional bond- and issuer-level features that could drive potential differential impacts of the pandemic on bond trading activities and pricing. First, different types of munis, classified by their sources of repayments, 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 of the specific project or source used to secure the bond. For a general obligation (GO) bond that is backed by the taxing power of governments, the concerns mostly lie in the decline in revenue from taxes and the higher expenditures for healthcare and social services. In our sample, unlimited GO bonds and revenue bonds each account for about one third of our sample, respectively, with the rest belonging to other bond types.

Second, the impact of the pandemic could vary for bonds in different sectors. 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

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

a harder hit.[15] We group municipal bonds into the following sectors: general, education, health & nursing care, housing & development, leisure, public service, transportation, and utility. The largest five sectors in our sample are education (31%), general (30%), utility (15%), transportation (9%), and health care (8%).

Third, 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.[16] 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). Our sample includes municipal bond issuers from all 50 states. The top three states with the most actively traded municipal bonds are California (13%), New York (12%), and Texas (10%), together accounting for 35% of bond-day observations in our sample.

3 Hypothesis development

In this section, we draw on existing literature and develop hypotheses to guide our empirical analysis. Our focus is on how the COVID-19 episode potentially changed market perceptions of mutual fund fragility risks and affected the assessment of such risks in the aftermath of the crisis. We start by hypothesizing how fragility risks posed by mutual fund materialize in the muni market during the crisis and how such risks are amplified by dealers. We then develop conjectures for pricing implications of mutual fund fragility risks in the post-crisis period and explore potential mechanisms for such lasting pricing effects.

[15] 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.

[16] 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.

3.1 Hypothesis development for crisis-time analysis

Most fixed income mutual funds perform substantial liquidity transformation. They offer immediate liquidity to investors by allowing redemption of shares on a daily basis. Meanwhile, many of the securities that they hold heavily rely on dealer intermediation and can be very illiquid. In the spirit of Diamond and Dybvig (1983), theoretical work in Chen, Goldstein, and Jiang (2010) and Zeng (2017) shows that such liquidity mismatch could incentivize fund investors to redeem ahead of others in the face of a negative shock and amplify withdrawals.[17]

Can large-scale redemptions from mutual funds destabilize the underlying fixed-income markets?[18] With municipal bond mutual funds holding low levels of cash and almost zero Treasury bonds, there is little alternative than to sell bonds to meet redemptions. Such redemption-induced bulk selling from mutual funds can lead to abnormally excessive trading in the muni market. Our first hypothesis tests this effect:

Hypothesis 1 (H1): *During the COVID-19 crisis, municipal bonds with larger exposures to mutual fund redemption risks experience more excessive trading volumes.*

A critical, but unexplored, determinant of the potential impact of mutual fund fire sales on the underlying markets is dealers' liquidity provision. For the muni market, dealers provide the vast majority of liquidity (see, for example, Harris and Piwowar, 2006; Green, Hollifield, and Schürhoff, 2007b). The muni market could withstand large temporary selloffs by mutual funds if dealers step up to absorb these sales. Two recent empirical studies show that, in general, dealer inventories declined at the height of the COVID-19 crisis for corporate bonds (see Kargar et al., 2020; and O'Hara and Zhou, 2020a). But what has not been addressed is how the pullback by dealers differs across bonds with different exposures to mutual fund run risks. Answering this question could reveal the role played by dealers in transmitting fragility risks posed by mutual funds to the financial system.

[17] Empirical evidence on how such first-mover advantage causes runs on fixed-income funds is provided in Feroli, Kashyap, Schoenholtz, and Shin (2014), Goldstein, Jiang, and Ng (2017) and Falato, Goldstein, and Hortaçsu (2020), among others.

[18] For empirical studies on the effects of mutual fund fire sales on the corporate bond market, see Choi, Hoseinzade, Shin, and Tehranian (2020); Jiang, Li, and Wang (2020); and Ma, Xiao, and Zeng (2020).

We conjecture that during the crisis dealer liquidity provision declines more for bonds with larger mutual fund exposures based on the following theoretical grounds. First, inventory risks are a key consideration in dealers' market making activities and their pricing strategies;[19] and dealers can suffer significant inventory costs during crisis periods (An, 2020). Such risks are likely to be heightened for bonds more subject to mutual fund fire sales. Second, trading frictions, such as searching and bargaining, can also affect dealer liquidity provision (Lagos, Rocheteau, and Weill, 2011). As the largest institutional investors, i.e., mutual funds, start to liquidate positions, locating counterparties becomes challenging for dealers in the retail-dominated muni market. Moreover, market-wide fear of mutual fund fragility hurts dealers' bargaining power in unwinding their positions in mutual-fund-held bonds, subjecting dealers to additional transaction losses. These arguments lead to our next hypothesis:

Hypothesis 2 (H2): *During the COVID-19 crisis, dealer on net sell more bonds with larger exposures to mutual fund redemption risks.*

Excessive selling by mutual funds (H1), amplified by dealers' pulling back from liquidity provisions (H2), are likely to exert substantial price pressures on bonds with larger mutual fund exposures. We test such price impact with the following hypothesis:

Hypothesis 3 (H3): *During the COVID-19 crisis, bonds with larger exposures to mutual fund redemption risks suffer more price depression.*

3.2 Hypothesis development for aftermath effects

Our hypotheses on the COVID-19 crisis period focus on impacts of mutual fund redemptions on the underlying market and highlight the dealers' roles in amplifying mutual fund fragility risks. But is this really the end of the story? In particular, could mutual funds' destabilizing effects during the crisis reshape market perceptions about potential risks posed by mutual

[19]See Chapter 2 of O'Hara (1995) for a review of inventory-based models of market making.

funds? If so, is this change of perceptions reflected in post-crisis market dynamics? We develop hypotheses to test for these aftermath effects.

The destabilizing effects caused by mutual fund runs during the COVID-19 crisis came about as a major shock to the muni market. Indeed, municipal bond mutual funds had attracted continuing inflows for over a year before the crisis. Thus, mutual fund redemption-induced fire sales could represent a regime-shift to the muni market. Although large-scale redemptions on muni funds ceased in April 2020, and since May 2020 funds have attracted persistent inflows, the pandemic continues to evolve, raising at least the nascent possibility that investors could run again on muni mutual funds. With market-wide awareness of mutual fund fragility risks, bonds bearing greater such risks are likely to be less attractive to market participants in the post-crisis period. We hypothesize that such market-wide perception changes are reflected in the post-crisis pricing of municipal bonds:

Hypothesis 4 (H4): *In the post-crisis period, yield spreads widen more in municipal bonds with greater mutual fund exposure.*

We explore two potential mechanisms for the post-crisis pricing effects of mutual fund fragility risks: a liquidity channel and a run-risk channel. First, a large literature shows that liquidity is an important factor in corporate bond yield spreads (see, for example, Chen, Lesmond, and Wei, 2007; and Bao, Pan, and Wang, 2011). If dealers revise their expectations from the COVID-19 episode and continue to be reluctant to facilitate trading in munis heavily held by mutual funds, then these bonds could suffer larger deterioration in liquidity and, hence, exhibit wider yield spreads. The nature of government interventions and features of the muni market could also contribute to this channel: Without the Federal Reserve acting as market maker of last resort as in the corporate bond market (O'Hara and Zhou, 2020a), and facing the perennial problem of limited ways to hedge risk in munis, dealers are likely to further curtail liquidity provisions in municipal bonds that bear potential mutual fund fire sale risks. We test for this liquidity channel of post-crisis pricing effects:

Hypothesis 5 (H5): *In the post-crisis period, dealers' inventories decline more in bonds with greater mutual fund exposures, and these bonds suffer more deterioration in liquidity.*

Second, the on-going nature of the pandemic suggests that the fear of another run on muni mutual funds could also drive lasting price effects. This run-risk channel implies that holders of bonds more likely to face runs would demand compensation for bearing this risk. If mutual fund ownership affects muni pricing due to funds' potential run risks after the crisis, we expect such pricing effects to be stronger for bonds held by mutual funds more susceptible to runs. We next test the run-risk channel:

Hypothesis 6 (H6): *Post-crisis pricing effects are stronger in municipal bonds held by mutual funds more susceptible to runs.*

4 Impact of mutual fund fire sales during the crisis

Our within-crisis analysis examines whether large-scale redemptions from mutual funds destabilize the underlying muni market. Specifically, we analyze trading activities across municipal bonds with different exposures to mutual fund runs at the height of the crisis (H1); dealer trading behavior and its role in amplifying mutual fund run risks (H2); and the direct price impact of mutual fund fire sales (H3).

4.1 Mutual fund redemptions and bond trading activities

We start with testing hypothesis H1. Figure 2 shows that the surge in muni trade volume within the two-week period March 9 to March 23, 2020 appears to be primarily concentrated in bonds held by mutual funds. To address the concern that certain bond characteristics, rather than mutual fund ownership, drive the unusual trading activities during the COVID-19 crisis,[20] we construct a bond-date sample that includes the two-week crisis period (from

[20]For example, short-term bonds are likely to have taken a harder hit in March as the rapid spread of the virus raised particular concerns on municipalities' abilities to deal with short-term liquidity pressures and

March 9 to March 20) and a pre-crisis period of the same length (from February 24 to March 6),[21] and estimate the following empirical model to control for potential impact of bond characteristics:

$$\log(Trading\ Volume_{i,t}) = \alpha + \beta_1 Held\ by\ MF_i + \beta_2 Crisis_t + \beta_3 Crisis_t \times Held\ by\ MF_i + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \epsilon_{i,t}, \quad (1)$$

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 $Held\ by\ MF_i$ is a dummy equal to one if the bond is held by mutual funds as of the end of 2019. $X_{i,t}$ represents a set of bond characteristics, including number of years since issuance (Age), number of years to maturity ($Year\ to\ Maturity$), coupon rate ($Coupon$), and the logarithm of total par amount outstanding ($\log(Amount\ Outstanding)$). Bond credit ratings are controlled by rating fixed effects (μ_{rating}).[22] We also control for bond type fixed effects (μ_{type}), bond sector fixed effects (μ_{sector}), and bond state fixed effects (μ_{state}). Standard errors are clustered at the bond and date levels.

Consistent with H1, Column (1) in Table 2 shows that compared to other bonds, those held by mutual funds experience an additional 29% increase in trading activities during the crisis period. Interestingly, for bonds not held by mutual funds, trading activities actually decline by 6.6% during the crisis period after controlling for bond characteristics. In addition, a bond's excessive trading during the crisis period increases in the levels of its mutual fund ownership. When we replace $Held\ by\ MF$ with $MF\ Share$, defined as the share of a bond's outstanding amount held by mutual funds at the most recent quarter-end (i.e., the end of 2019), the coefficient of the interaction of $MF\ Share$ and $Crisis$ remains positive and highly

meet their debt obligations in the near future. Also, municipal bonds in certain sectors like transportation and nursing homes likely faced more severe stress.

[21] 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.

[22] Bond ratings are categorized into AAA, AA, A, BBB, and high-yield. Note that high-yield bonds make up less than 1% of our sample.

significant (Column (2)). Controlling for general trends in muni market trading by including day fixed effects (μ_t) (Column (3)), and unobservable issuer characteristics by including issuer fixed effects (μ_{issuer}) (Column (4)) does not change our conclusion.[23] Lastly, our results are robust when we control for time-varying effects of bond and issuer characteristics, represented by various two-way fixed effects (rating×day, type×day, sector×day, and issuer×day) and the interaction of $X_{i,t}$ and the $Crisis$ dummy (Column (5)). Although our sample size decreases notably in this strictest specification, we find that bonds held more by mutual funds are traded more heavily in the crisis when compared to similar bonds from the same issuer traded on the same day.

To establish further the link between mutual fund outflows and muni trading, we use information on both CUSIP-level holdings and daily fund flows, and construct a bond-level mutual fund flow measure, $MF\ Outflow_{i,t}$, which is defined as:

$$MF\ Outflow_{i,t} = \frac{\sum_{k=1}^{K} Holding\ Amount_{i,k} \times Outflow_{k,t-1,t}}{\sum_{k=1}^{K} Holding\ Amount_{i,k}}, \tag{2}$$

where $Outflow_{k,t-1,t}$ is fund k's cumulative percentage outflows (adjusted for fund returns) over the most recent two business days (i.e., day $t-1$ and day t), and $Holding\ Amount_{i,k}$ is the dollar amount of municipal bond i held by fund k as of the end of 2019.[24]

We include only municipal bonds that are held by mutual funds as of the end of 2019 to analyze the impact of mutual fund flows on their trading activities during the crisis period (i.e., from March 9 to March 20, 2020) and estimate the following model:

$$\log(Trading\ Volume_{i,t}) = \alpha + \beta MF\ Outflow_{i,t} + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \mu_t + \epsilon_{i,t}. \tag{3}$$

Consistent with flow induced trading, Column (1) of Table 3 shows that the coefficient of $MF\ Outflow$ is positive and highly significant. Specifically, a one-percentage-point increase

[23] Once we control for issuer fixed effects, state fixed effects become redundant.
[24] Our results are qualitatively similar when using outflows over the most recent one or three business days.

in the outflow of a bond's holding funds is associated with a 24% increase in that bond's trading activities during the crisis. In addition, *MF Share* continues to have a strong positive impact on trading volume when included as an additional explanatory variable, indicating that in addition to redemption-induced liquidation, mutual funds may also engage in preemptive selling of their holdings with the fear for additional outflows during the crisis (Column (2)). Again, controlling for issuer fixed effects (Column (3)) does not change our results. Our conclusion holds when we control for time-varying impacts of bond and issuer characteristics (Column (4)). Together, results in Table 2 and Table 3 lend strong support to hypothesis (H1) that the sharp increase in trading activities of municipal bonds during the crisis period can be attributed to bonds with mutual fund holders, likely stemming from mutual funds selling their holdings in response to extraordinary outflows.

4.2 Dealer trading and mutual fund exposures during the crisis

How do dealers act in bonds facing mutual fund selloffs? Figure 3 shows that dealers' cumulative inventories in bonds held by mutual funds and other bonds are at similar levels over the five-month period prior to the COVID-19 crisis.[25] 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 (Zeng (2017)). When large outflows from mutual funds start on March 9, however, dealers quickly shift to selling bonds which are likely to face unusually high selling pressures from mutual funds. During the two-week crisis period, dealers' cumulative inventories in bonds held by mutual funds drop by over $1 billion. Dealers' drastic reversal 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 dealers' response to mutual fund selloffs as hypothesized in H2, we

[25] We focus on dealers' inventory adjustments through the secondary market. See the description of Figure 3 for more details about the calculation of dealers' total cumulative inventory.

use the sample that covers both the pre-crisis and crisis periods and estimate the following empirical model:

$$Dealer\ Net\ Purchase_{i,t} = \alpha + \beta_1 Held\ by\ MF_i + \beta_2 Crisis_t + \beta_3 Held\ by\ MF_i \times Crisis_t + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \epsilon_{i,t}, \quad (4)$$

where $Dealer\ Net\ Purchase_{i,t}$ is the difference between dealers' aggregate purchases from customers and their aggregate sales to customers in bond i on day t. $Dealer\ Net\ Purchase_{i,t}$ is measured in million dollars and winsorized daily at the top and bottom 0.5% levels. Independent variables are defined as in Model (1). We also control for the potential impact of a bond's overall trading activities on dealer trading. Standard errors are clustered at the bond and date levels.

Column (1) of Table 4 shows that the coefficient of $Held\ by\ MF$ is positive and significant, in line with dealers accumulating greater inventories in bonds held by mutual funds during the pre-crisis period. More importantly, the interaction of $Held\ by\ MF$ and $Crisis$ is negative, highly significant, and substantially larger compared with the coefficient of $Held\ by\ MF$. Specifically, relative to bonds not held by mutual funds, dealers on average sell more bonds with mutual fund holders during the crisis time (by around $28,000 per bond-day, on net). We obtain consistent results when replacing $Held\ by\ MF$ with $MF\ Share$ (Column (2)). Our results are robust to controlling for general time trends (Columns (3)), unobservable issuer characteristics (Column (4)), and potential time-varying bond and issuer-specific impacts (Column (5)). These results support hypothesis (H2) and highlight the role played by dealers in amplifying fragility risks posed by mutual funds.

4.3 Price impact of mutual fund fire sales

As hypothesized in H3, mutual funds' excessive selling during the crisis and dealers' pullback from providing liquidity in mutual-fund-held bonds likely drive price pressures in these bonds.

To test this hypothesis, we estimate the following model:

$$Yield\ Spread_{i,t} = \alpha + \beta_1 Held\ by\ MF_i + \beta_2 Crisis_t + \beta_3 Crisis_t \times Held\ by\ MF_i + \gamma X_{i,t} + \mu_{rating} + \mu_{type} + \mu_{sector} + \mu_{state} + \epsilon_{i,t}, \quad (5)$$

where $Yield\ Spread_{i,t}$ refers to yield spread of bond i on day t, relative to the same-day same-maturity Treasury bond yield and adjusted for both federal and state taxes. Independent variables are defined the same as in Model (4). Standard errors are clustered at the bond and date levels.

Consistent with hypothesis (H3), while all municipal bonds experience a surge in yield spreads during the crisis, bonds held by mutual funds experience an additional increase of 16 basis points in their crisis-time yield spreads after controlling for bond characteristics (Column (1) of Table 5). We obtain consistent results when replacing the *Held by MF* dummy with the continuous *MF Share* (Column (2)). Such effects are robust to the inclusion of time fixed effects (Column (3)), issuer fixed effects (Column (4)), as well as time-varying effects of bond and issuer characteristics (Column (5)).

We also link yield spreads of munis to recent redemptions from their mutual fund holders. Specifically, we replace with $Yield\ Spread_{i,t}$ with $log(Trading\ Volume_{i,t})$ and re-estimate Model (3). Table 6 shows that mutual fund flow-induced trading likely has pushed bond yield spreads higher during the crisis period. Column (1) shows that during the crisis, a bond's yield spread widens by 5 basis points for a one-percentage-point increase in the outflow of the bond's mutual fund holders. In addition, yield spreads tend to be higher in bonds held more by mutual funds, suggesting that not only the realized outflows, but also the concerns for future mutual fund outflows could have precipitated trading and thus exerted price impact in the muni markets (Column (2)). Our results are robust to controlling for issuer fixed effects (Column 3)) and time varying effects of bond and issuer characteristics (Column (4)). Together, these results lend additional support to hypothesis (H3) and illustrate the price destabilizing effects that mutual fund runs impose on the muni markets during the crisis.

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

In this section, we analyze the aftermath effects of the crisis on muni market dynamics and explore whether the crisis episode has reshaped the market's assessment of mutual fund fragility risks. We first test for potential pricing effects of such risks in the post-crisis period (H4). We then explore two potential mechanisms for such effects: a liquidity channel (H5) and a run-risk channel (H6). Finally, we test two alternative explanations for our findings: (i) slow recovery of fire sale prices and (ii) reaching for yield by mutual funds.

5.1 Yield spreads and mutual fund fragility risks

As hypothesized in H4, given the destabilizing effects that the run on mutual funds causes to the muni market during the COVID-19 crisis, bonds with greater exposure to mutual fund fragility risks may be less attractive to market participants in the post-crisis period. Such a change in perception of mutual fund fragility risks could have important pricing implications. Indeed, Figure 4 shows that after the normalization of mutual fund flows (from the beginning of May to the end of September, 2020), a wedge persists between the yield spreads of bonds held by mutual funds and those that are not.

To formally test the effects of mutual fund ownerships on post-crisis bond yield spreads, we use the sample that spans the period from October 1, 2019 to September 30, 2020, but excludes March and April of 2020, and estimate the following panel regression:

$$Yield\ Spread_{i,t} = \alpha + \beta_1 \times MF\ Share_{i,t} + \beta_2 \times PostCrisis_t \times MF\ Share_{i,t} + \gamma X_{i,t} + \mu_{rating,t} + \mu_{type,t} + \mu_{sector,t} + \mu_{state,t} + \epsilon_{i,t}, \quad (6)$$

where $Yield\ Spread_{i,t}$ refers to the tax-adjusted yield spread of bond i on day t. $PostCrisis_t$ is a dummy that takes the value one for the period from May 1 to September 30, 2020.[26]

[26]Note that $PostCrisis_t$ is rendered redundant with the inclusion of two-way fixed effects.

$MF\ Share_{i,t}$ is the ownership of bond i by mutual funds at the most recent quarter-end. Control variables are defined as in Model (5). $\mu_{rating,t}$ represents rating×year-month fixed effects, and $\mu_{type,t}$, $\mu_{sector,t}$, and $\mu_{state,t}$ are similarly defined. These two-way fixed effects control for time-varying impacts of bond rating, type, sector, and issuer location on yield spreads. Standard errors are clustered at the bond and date levels.

We exclude March and April of 2020 from this regression sample to minimize the immediate impact of mutual fund runs and the following government interventions on the dynamics in the muni market during the post-crisis period. Given that municipal mutual funds experienced persistent inflows since the start of May (as they did in the pre-crisis period), we see no reason to believe that mutual fund redemptions directly drive the post-crisis price dynamics. Rather, it is more likely that the salient destabilizing role played by mutual funds during the crisis and lingering pandemic concerns have reshaped market participants' perceptions of the potential fragility risks posed by municipal mutual funds.

Column (1) of Table 7 shows that the widening in yield spreads during the post-crisis period significantly increases in mutual fund ownership. Specifically, a bond with average mutual fund ownership of 33% experiences an additional increase of 9 basis points in its post-crisis yield spread (equivalent to 9% of median-level yield spread across all bonds over the sample period) compared to a bond not held by mutual funds. Our results are robust when we control for time-varying effects of bond and issuer characteristics (Columns (2)-(3)). Moreover, these findings are robust across subsamples based on a bond's credit rating, sector, or type. Specifically, Table A.1 shows that while the post-crisis impact of $MF\ Share$ on muni yield spread tends to be stronger in lower rated bonds, in sectors hit harder by the Covid-19 pandemic, and in non-GO bonds, the effects are significant across all subsamples.

Together, results in Table 7 and Table A.1 support hypothesis H4 and suggest that the COVID-19 crisis has profoundly changed the way that the market assesses fragility risks posed by mutual funds. We now turn to exploring potential mechanisms for the post-crisis pricing effects of mutual fund fragility risks.

5.2 Why it happens? A liquidity channel

One possible explanation for the wider yield spreads in bonds with greater exposure to mutual fund fragility risks is that these bonds suffer greater deterioration in liquidity due to lower liquidity provision after the crisis. Specifically, if dealers attach a higher risk to potential mutual fund runs, their reluctance to provide liquidity could continue in the aftermath of the crisis. Indeed, Figure 3 shows that in aggregate, dealers continue to lower their inventories in municipal bonds held by mutual funds in the post-crisis period, despite the recovery of mutual fund flows. The magnitude of dealer inventory decline in mutual-fund-held bonds far exceeds that in bonds not held by mutual funds.

This post-crisis dealer behavior in the muni market contrasts sharply with that in the corporate bond market which also suffered large mutual fund outflows at the height of the crisis.[27] O'Hara and Zhou (2020a) find that as in the muni markets, dealers are net sellers in the corporate bond market during the crisis period. 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.[28] 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 is likely that dealers kept shrinking their inventory of municipal bonds, especially those bearing potential mutual fund fire sale risks.

[27]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).

[28]Federal Reserve facilities related to municipal bonds either target the primary market (MLF), or the short-term municipal bond markets (MMLF and CPFF), or a small subset of dealers (PDCF).

To formally test dealers' post-crisis behaviors, we use a bond-day sample spanning from October 1, 2019 to September 30, 2020 (excluding March and April of 2020) and estimate the following empirical model:

$$Cumu\ Inventory\ Change_{i,t} = \alpha + \beta_1 \times MF\ Share_{i,t} + \beta_2 \times PostCrisis_t \times MF\ Share_{i,t} + \gamma X_{i,t} + \mu_{rating,t} + \mu_{type,t} + \mu_{sector,t} + \mu_{issuer,t} + \epsilon_{i,t}, \quad (7)$$

where $Cumu\ Inventory\ Change_{i,t}$ refers to the cumulative dealer inventory changes in bond i since October 1, 2019, in million dollars and winsorized daily at the top and bottom 0.5% levels. Independent variables and fixed effects are defined as in Model (6), and standard errors are clustered at the bond and date levels.

Results in Table 8 support our contention that fear for mutual fund fragility risks has greatly affected dealers' willingness to take inventories of bonds bearing such risks. Columns (1)–(2) show that in the post-crisis period, dealers' cumulative inventories decline more in bonds with higher mutual fund ownerships, after controlling for time-varying impacts of bond and issuer characteristics. Specifically, compared to municipal bonds not held by mutual funds, those with average mutual fund ownership of 33% experience an additional $246 thousand decrease in dealer inventory over the post-crisis period (column (1)).

How does the change in dealers' behavior towards mutual-fund-held bonds affect the post-crisis liquidity of the muni market? One key challenge in addressing this question lies in the estimation of reliable bond-level liquidity measures. Because the muni market is an OTC market, quotes are indicative and only provided by dealers when approached by investors. In addition, a significant portion of muni investors tend to buy and hold their investments to maturity, and secondary market trading activities in munis are usually very limited.

To shed light on whether post-crisis liquidity deteriorates more for municipal bonds held by mutual funds, we estimate a realized bid-ask spread measure. Given the importance of trade size in affecting muni prices (Schultz, 2012), we first calculate a bond's volume-weighted average customer buy prices ($Ask_{i,t}$) and its volume-weighted average customer sell prices

($Bid_{i,t}$) in a given bond and on a given day. We then calculate a bond-day level measure ($Spread_{i,t}$) by taking the difference between $Ask_{i,t}$ and $Bid_{i,t}$.[29]

We then re-estimate model (7) by replacing $Cumu\ Inventory\ Change_{i,t}$ with $Spread_{i,t}$ and report the regression results in columns (3)–(5) of Table 8. To be included in our sample, we require a bond to be traded at least 30 days over the sample period. As expected, our sample size shrinks substantially due to our focus on more frequently traded bonds. Nevertheless, in this limited sample, we find evidence that liquidity deteriorates more in bonds held more by mutual funds during the post-crisis period (column (3)). We also re-estimate the empirical model on subsamples of even more frequently traded bonds and find consistent results (columns (4)–(5)). Together, these findings support H5 and suggest that potential fragility risks introduced by mutual funds have changed dealer behavior and liquidity conditions in the muni market after the COVID-19 crisis.

5.3 Why it happens? A run-risk channel

Our results on the pricing of mutual fund fragility risks are obtained for the post-crisis period, during which muni funds actually attracted persistent inflows. Although the muni market no longer faces immediate selloffs by mutual funds, the on-going nature of the pandemic is certainly consonant with the fear that investors could run again on mutual funds.

We investigate a second, fund-linked channel through which mutual fund run risks affect muni market pricing. We identify fund-level factors that could drive investor outflows in times of stress and link those latent run-risk sources to the pricing of individual bonds. Intuitively, if mutual fund ownership affects muni pricing through the channel of potential run risks in the post-crisis period, we should obtain much stronger pricing effects for bonds bearing higher mutual fund run risks.

We draw on the literature to identify four measures of mutual fund fragility risks based on

[29]It is worth noting that due to high illiquidity in the municipal bond market, we are unable to obtain valid realized spread estimates for the majority of the bond-day observations. We trim $Spread_{i,t}$ at the top and bottom 1% levels to reduce the potential impact of noisy estimates.

funds' portfolio holdings. The first three measures are a fund's exposure to sectors most hit by the pandemic, the average maturity of a fund's portfolio, and the average illiquidity levels of a fund's portfolio, identified by Falato, Goldstein, and Hortaçsu (2020) as factors driving fixed-income fund outflows during the COVID-19 crisis. The fourth measure is a fund's cash holding, which is shown to be actively managed by fund managers in anticipation of potential investor outflows by Chernenko and Sunderam (2016) and Chernenko and Sunderam (2020). We group munis into subsamples based on their holding funds' aforementioned fragility sources, and test whether the effects of mutual fund holding shares on muni yield spreads during the post-crisis period intensify when a bond's holding funds are more susceptible to investor runs. In this subsample analysis, which essentially uses triple differences, we exclude bonds not held by mutual funds (which, by definition, bear no latent run risks from mutual funds).

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

$$Fund\ Run\ Risk_{j,t}^{Type} = \frac{\sum_i Bond\ Risk_{i,t}^{Type} \times Holding\ Amount_{i,j,t}}{\sum_i Holding\ Amount_{i,j,t}}, \tag{8}$$

where $Bond\ Risk_{i,t}^{Type}$ indicates one of the followings for the first three types of run risk measures: a dummy indicating whether bond i is in the sectors hit hardest by the pandemic (defined as transportation, health & nursing care, and leisure), the remaining time to maturity of bond i, or the illiquidity level of bond i. $Holding\ Amount_{i,j,t}$ represents the par amount of bond i held by fund j. Therefore, $Fund\ Run\ Risk_{j,t}^{Type}$ represents fund j's sector exposure to the Covid-19 crisis, average portfolio maturity, or the overall illiquidity level of its holdings.[30] For $Fund\ Run\ Risk_{j,t}^{Cash}$, we obtain funds' cash holdings from Morningstar,

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

which is available monthly (or quarterly) for a subset of municipal bond funds.

The second step is to calculate the bond-level run risk measure stemming from the bond's investing mutual funds:

$$Bond\ Run\ Risk_{i,t}^{Type} = \frac{\sum_j Fund\ Run\ Risk_{j,t}^{Type} \times Holding\ Amount_{i,j,t}}{\sum_j Holding\ Amount_{i,j,t}}, \qquad (9)$$

where $Fund\ Run\ Risk_{j,t}^{Type}$ and $Holding\ Amount_{i,j,t}$ are defined in Equation (8). Intuitively, $Bond\ Run\ Risk_{i,t}^{Type}$ represents on average how much run risks bond i's investing mutual funds entail, weighted by each mutual fund's holding amount of bond i. We then use the medians of four types of $Bond\ Run\ Risk_{i,t}$ to split our bond-day sample into subgroups.

Turning to our hypotheses, we expect the impact of $MF\ Share$ on the yield spread of a municipal bond will be stronger when its investing funds' portfolios are more exposed to the pandemic. To test this first conjecture, we use the sample of mutual-fund-held bonds spanning from October 1, 2019 to September 30, 2020 (excluding March and April) and estimate the following model for subsamples sorted by $Bond\ Run\ Risk_{i,t}^{Type}$ (with $Type$ defined as sector exposures to the Covid-19 crisis):

$$\begin{aligned} Yield\ Spread_{i,t} &= \alpha + \beta_1 \times MF\ Share_{i,t} + \beta_2 \times PostCrisis_t \times MF\ Share_{i,t} + \\ &\gamma_1 \times X_{i,t} + \gamma_2 \times PostCrisis_t \times X_{i,t} + \mu_{rating,t} + \mu_{type,t} + \mu_{sector,t} + \mu_{issuer,t} + \epsilon_{i,t}. \qquad (10) \end{aligned}$$

Results in Columns (1)–(2) in Table 9 support our hypothesis that the post-crisis effect of $MF\ Share$ on yield spreads gets stronger when a bond's holding funds are more vulnerable. While the coefficient of the interaction of $MF\ share$ and $PostCrisis$ is highly significant in both subsamples, it is significantly larger in the subsample with large COVID-19 exposure.

Second, we expect funds holding longer maturity bonds to be more affected by market fluctuations given their higher interest rate risks, and hence be more susceptible to greater outflow pressures. Columns (3)–(4) show that the coefficient of the interaction of $MF\ share$ and $PostCrisis$ is substantially larger when bonds' mutual fund holders' portfolio maturities

measures for the majority of municipal bonds.

are longer.

Third, 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). 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. Results in Columns (5)–(6) confirm this conjecture.

Finally, cash holdings of fixed-income mutual funds can serve as effective buffers for investor redemptions, as mutual funds can resort to their cash positions rather than selling illiquid assets like municipal bonds in the face of outflows. Cash holdings for municipal bond mutual funds are critical in times of stress, as these funds hold almost zero Treasury bonds, which are commonly considered liquidity buffers for other fixed-income mutual funds. Thus, muni funds with lower cash reserves are likely to be more susceptible to fragility risks associated with investor redemptions. Indeed, columns (7)–(8) show stronger pricing effects in the subsample with lower cash holdings.

Together, these results show that the riskiness of mutual fund holdings carry important implications for municipal bond pricing in the post-crisis period, providing strong evidence for H6. These results not only reveal the underlying mutual fund run-risk sources that drive individual bond pricing, but also point to the sophistication of the muni market in identifying and pricing in these latent risk factors.

5.4 Testing for alternative explanations

We address the potential concerns that there could be alternative explanations for the post-crisis pricing effects. Specifically, we test two alternative stories: (i) slow recovery from fire sale prices and (ii) reaching for yield by mutual funds.

One alternative explanation is that the wider post-crisis yield spreads on bonds with larger exposure to mutual funds reflect slow recovery from fire sale prices for bonds heavily sold by mutual funds during the crisis period. If crisis-time price impacts of mutual fund fire sales took time to reverse, then those directly affected bonds could exhibit wider yield spreads in the aftermath.[31] To address this concern, we use two approaches to exclude bonds that are likely subject to mutual fund fires sales at the height of the COVID-19 crisis.

Our first approach is based on bond trading information. Specifically, we exclude mutual-fund-held bonds that are ever traded during the crisis period. Our second approach is based on mutual fund holding information. Specifically, we exclude bonds that experience net selling from mutual funds in the first quarter of 2020 (by comparing a bond's total holding amount by mutual funds as of the end of 2019 and the end of the first quarter of 2020). We then re-estimate Model (6) using the remaining bonds after applying the aforementioned filters, while controlling for time-varying effects of bond characteristics and issuers. As shown in columns (1)–(2) of Table 10, in both approaches of restricting our sample, the estimated coefficient on the interaction of $MF\ Share$ and $PostCrisis$ remains positive and highly significant.[32] These results suggest that slow recovery from crisis-time fire sale prices is unlikely to be a key driver for the post-crisis pricing effects.

Another alternative explanation for our finding 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.[33] In other words, it might be that mutual funds actively initiate or increase their holdings in municipal bonds with higher yields in the post-crisis period, in the face of near zero policy rates.[34]

To address this concern, we focus on a subsample of bonds whose mutual fund holdings remain unchanged over the second quarter of 2020. Intuitively, to reach for yields, mutual

[31] See Coval and Stafford (2007) for price reversal of flow-induced selling in the context of equity mutual funds.

[32] It is worth noting that our exclusion criteria are stricter than necessary, as we basically exclude all mutual-fund-held bonds that were traded/sold during the crisis, which might not be subject to mutual fund fire sales.

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

[34] See Becker and Ivashina (2015) for reaching for yield by insurance firms, and Choi and Kronlund (2018) for similar behavior by mutual funds.

funds would increase their holdings of higher-yield bonds and/or decrease their holdings of lower-yield bonds. Therefore, 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 for this subsample.

Specifically, we use a sample that spans from October 1, 2019 to June 30, 2020 (excluding March and April of 2020) and include only bonds whose total par amount held by mutual funds do not change from the first quarter-end to the second quarter-end in 2020. We then re-estimate Model (6) controlling for time-varying effects of bond characteristics and issuers. Results are presented in columns (3)–(4) of Table 10. Column (1) shows that the coefficient of the interaction of $MF\ Share$ and $PostCrisis$ remains positive and highly significant. Its economic magnitude remains qualitatively the same compared to that reported in Column (5) of Table 7. In Column (2) we further restrict the sample by excluding bonds not held by mutual funds in any of the first two quarter-ends of 2020 and obtain consistent results. In sum, we find no support for the argument that our results are driven by mutual funds reaching for yields in the post-crisis period.

6 Conclusion

The COVID-19 crisis provides an opportunity to analyze the destabilizing effects from the interactions of mutual funds and dealers under systemic stress and to examine the impact they exert on the underlying muni market in the aftermath of the crisis. During the crisis, mutual fund redemptions destabilized the underlying muni markets. Compared to other bonds with similar characteristics, bonds held by mutual funds traded excessively more, especially when their holding funds suffered larger outflows. Such destabilizing effects were amplified by dealers at the height of the crisis, as dealers shifted from buying to selling in bonds that likely faced mutual fund selling pressures. As a result, mutual-fund-held bonds suffered greater price pressures.

Equally important, the crisis-time manifestation of mutual fund destabilizing effects and dealers' amplification of such effects seem to have reshaped the market's perceptions of potential mutual fund fragility risks. We find that in the aftermath of the crisis, the muni market prices in fire sale risks from potential mutual funds runs, with bonds held more by mutual funds exhibiting wider yield spreads. Such lasting pricing effects potentially reflect liquidity changes in these bonds. Following the stabilization of mutual fund flows, muni dealers' reluctance to intermediate muni trading continues, and their liquidity provisions decline more in bonds with greater mutual fund exposures. We also show that the pricing effects of mutual fund fragility risks are stronger when the assets of a bond's mutual fund holders are more exposed to the pandemic, have longer maturity, are less liquid, or contain less cash.

Our study underscores the need to understand and address the threats posed by mutual funds to financial stability, especially in an illiquid market that largely relies on dealers for intermediation. 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 redemption is not limited to the fund itself, and can have a broader and lasting impact on underlying markets. In addition, our results highlight the role played by dealers in transmitting the fragility risks posed by mutual funds, as the ultimate impact of such risks on the muni markets largely relies on dealers' capability of absorbing redemption-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 fragility risks posed by mutual funds.

Our findings suggest that recent regulatory efforts to address fragility concerns in mutual funds (e.g., introducing swing pricing) should not be limited to the mutual fund industry. In particular, the role of dealers in transmitting mutual fund fragility risks deserves further study. Our paper also highlights the importance of assessing financial stability implications of various post-financial-crisis banking regulations. Although these regulations may increase the resilience of the banking system, they may also hamper dealers' liquidity provision and render over-the-counter markets more vulnerable to disruptions, such as those caused by mutual fund fire sales.

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Figure 1: **AUMs and flows in municipal bond mutual funds**

The top panel of this figure shows the daily time series of total assets under management (AUM) for municipal bond mutual funds (as defined by Morningstar), 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. The sample period is from November 2019 to September 2020. Both panels are based on daily AUMs and estimated flows obtained from Morningstar, aggregated from share-class levels to fund levels. We exclude funds without such daily information.

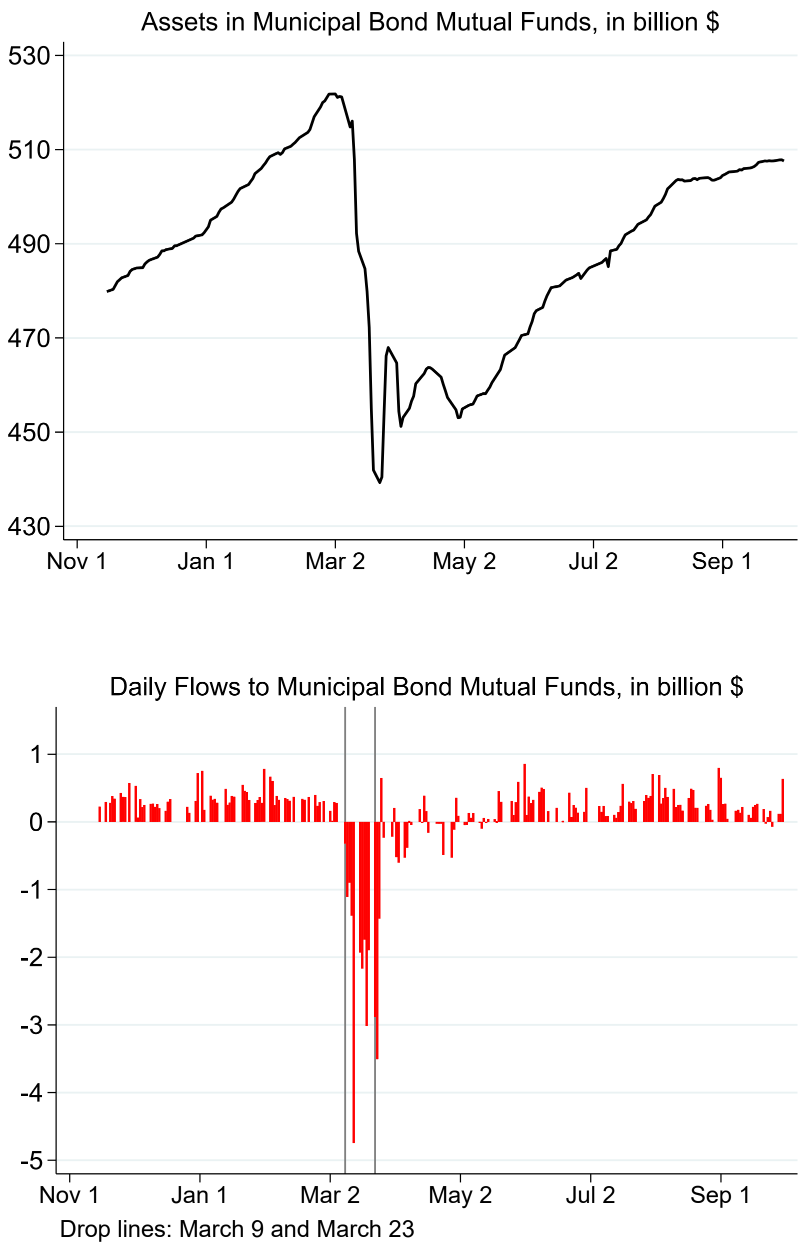

Figure 2: **Municipal bond trading volume**

The top panel shows the daily time series of total trading volume of municipal bonds, in billion dollars. The bottom panel shows trading volumes of municipal bonds by their mutual fund ownership. The sample period spans one year from October 1, 2019 to September 30, 2020. 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, those with insurance, and those with floating coupon rates.

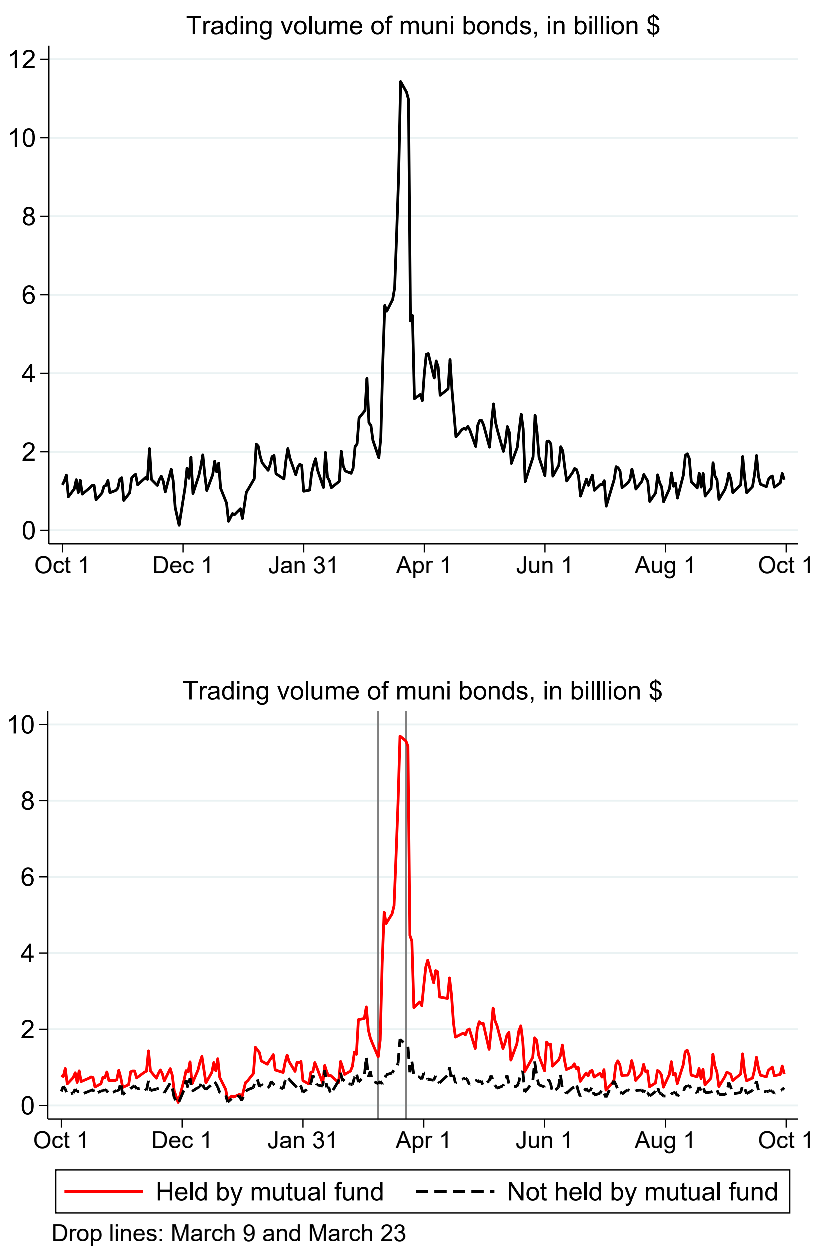

Figure 3: **Municipal bond dealer inventory: by mutual fund ownership**

This figure shows the daily time series of total dealer inventory of municipal bonds by their mutual fund ownership, cumulative from zero since October 1, 2019 and in billion dollars. The sample period spans one year from October 1, 2019 to September 30, 2020. 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 by U.S. insular areas, those with insurance, and those with floating coupon rates. To minimize the effects of newly-issued and maturing bonds on dealers' inventory, we also require that bonds be issued before July 1, 2019 (i.e., at least three months before the sample starts) and mature after October 1, 2021 (i.e., at least one year after the sample ends). We first calculate dealers' inventory change for each bond on each trading day and winsorize such bond-level inventory changes at the top and bottom 0.1% levels within each day. We then aggregate the daily bond-level inventory changes to daily market-wide inventory change, separately for bonds held by mutual funds and those not. Finally, we cumulate daily market-wide inventory changes from October 1, 2019 through September 30, 2020.

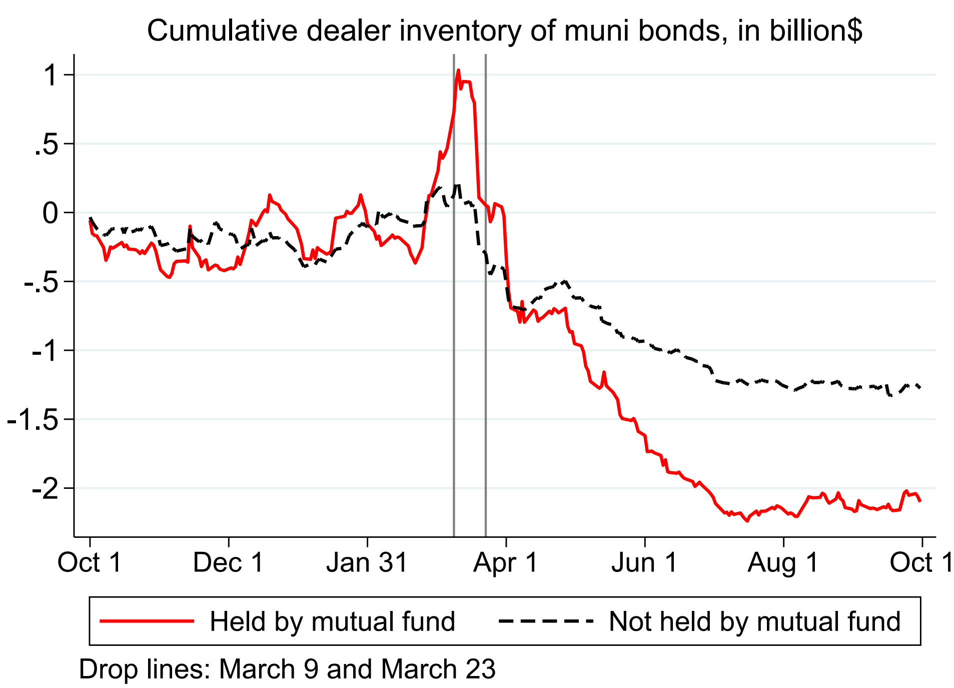

Figure 4: **Municipal bond yield spreads: by mutual fund ownership**

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. The sample period spans one year from October 1, 2019 to September 30, 2020. 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, those with insurance, and those with floating coupon rates.

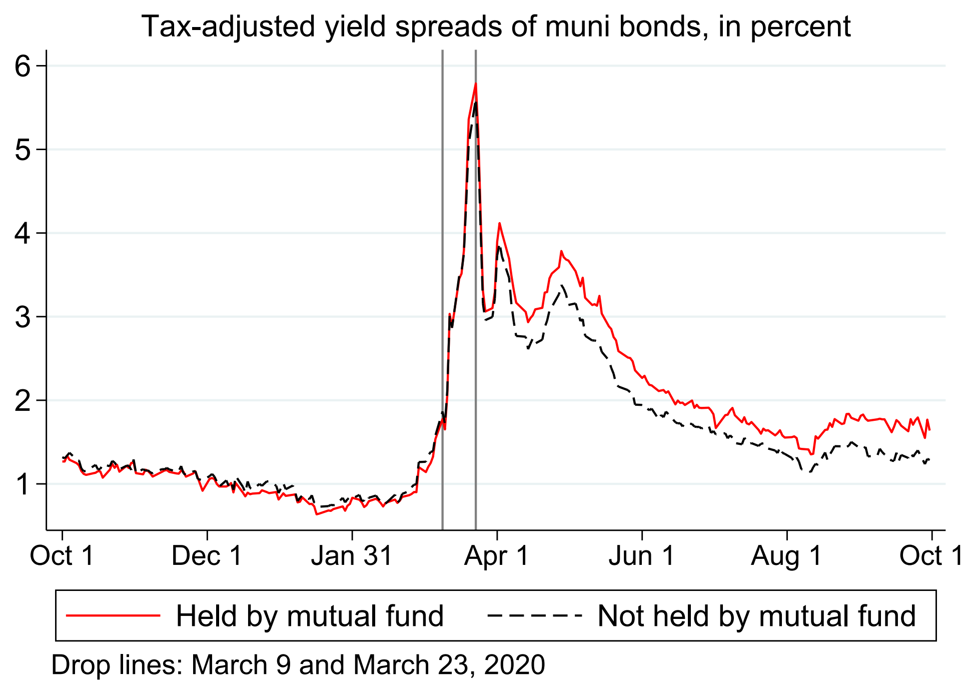

Table 1: **Summary statistics for pre-crisis municipal bonds**

This table provides summary statistics for municipal bonds traded during the pre-crisis period (from October 1, 2019 to February 28, 2020), divided into two groups based whether they are held by any mutual funds as of the most recent quarter end. Yield spread is relative to the same-day same-maturity Treasury bond yields and adjusted for both federal tax and state tax. For bond rating, we assign the value of 1 to bonds with the highest rating (AAA), 2 to bonds with AA rating, 3 to bonds with A rating, 4 to bonds with BBB ratings, and 5 to bonds with high-yield rating, which makes up less than 1% of the sample. Trading volume is aggregated at day level for each bond. MF *share* stands for mutual fund share and is defined as total mutual fund holding amount as a share of the bond's outstanding amount (between 0 and 1), winsorized at the top 1% level. We first take the average of all variables within each bond for the bond-day sample and then calculate summary statistics based on bond-level observations. 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, those with insurance, and those with floating coupon rates.

	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 (%)	37,862	0.95	0.69	0.91	111,334	0.96	0.74	0.79
Rating	37,862	2.28	2	0.84	111,334	1.97	2	0.65
Coupon	37,862	4.80	5	0.56	111,334	4.05	4	0.97
Age (in years)	37,862	4.40	3.86	2.98	111,334	4.40	4.03	2.67
Year to maturity	37,862	10.26	8.64	7.24	111,334	8.14	6.94	5.66
Daily trading volume ($)	37,862	325,718	62,500	1,547,782	111,334	135,683	36,667	1,047,012
Amount outstanding ($)	37,862	23,100,000	11,900,000	38,600,000	111,334	3,536,012	1,855,000	5,589,120
MF share	37,862	0.33	0.28	0.25	111,334	0	0	0

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

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

Dependent variable: log(Trading volume)					
	(1)	(2)	(3)	(4)	(5)
Held by MF×Crisis	0.293***				
	(7.10)				
MF share×Crisis		0.924***	0.926***	0.904***	0.799***
		(8.02)	(8.03)	(8.22)	(7.57)
Held by MF	0.059*				
	(2.06)				
MF share		0.550***	0.548***	0.465***	0.472***
		(8.96)	(8.92)	(8.10)	(6.57)
Crisis	-0.066***	-0.058***			
	(-3.03)	(-2.96)			
Bond controls	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes	
Type FE	Yes	Yes	Yes	Yes	
Sector FE	Yes	Yes	Yes	Yes	
State FE	Yes	Yes	Yes		
Date FE			Yes	Yes	
Issuer FE				Yes	
Rating×Date FE					Yes
Type×Date FE					Yes
Sector×Date FE					Yes
Issuer×Date FE					Yes
Bond controls×Crisis					Yes
Adj. R^2	0.062	0.078	0.078	0.118	0.102
N of obs.	197016	197016	197016	195372	157038

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

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

Dependent variable: log(Trading volume)				
	(1)	(2)	(3)	(4)
MF outflow	0.244***	0.207***	0.192***	0.186***
	(9.22)	(7.59)	(9.18)	(8.26)
MF share		1.457***	1.281***	1.220***
		(13.94)	(11.64)	(11.53)
Bond controls	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	
Type FE	Yes	Yes	Yes	
Sector FE	Yes	Yes	Yes	
State FE	Yes	Yes		
Date FE	Yes	Yes	Yes	
Issuer FE			Yes	
Rating×Date FE				Yes
Type×Date FE				Yes
Sector×Date FE				Yes
Issuer×Date FE				Yes
Adj. R^2	0.076	0.102	0.159	0.150
N of obs.	26996	26996	26394	21264

Table 4: **Mutual fund ownership and dealer intermediation during crisis**

The dependent variable is daily dealer net purchase (i.e., net change in dealer inventory) of individual municipal bond, in million dollars, winsorized daily at the top and bottom 0.5% levels. The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from February 24 to March 20, 2020. *Crisis* is a dummy variable that equals to one for the period of March 9 to March 20, 2020. *Held by MF* is a dummy that equals to one if the bond is held by mutual funds as of the end of 2019. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the end of 2019) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond controls* × *Crisis* indicates the interaction terms between the *Crisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: Dealer net purchase					
	(1)	(2)	(3)	(4)	(5)
Held by MF×Crisis	-0.028***				
	(-3.13)				
MF share×Crisis		-0.092**	-0.091**	-0.086**	-0.045**
		(-2.76)	(-2.72)	(-2.57)	(-2.81)
Held by MF	0.013**				
	(2.24)				
MF share		0.049***	0.050***	0.045***	0.029**
		(3.72)	(3.82)	(3.44)	(2.78)
Crisis	-0.011	-0.012*			
	(-1.54)	(-1.83)			
Bond controls	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes	
Type FE	Yes	Yes	Yes	Yes	
Sector FE	Yes	Yes	Yes	Yes	
State FE	Yes	Yes	Yes		
Date FE			Yes	Yes	
Issuer FE				Yes	
Rating×Date FE					Yes
Type×Date FE					Yes
Sector×Date FE					Yes
Issuer×Date FE					Yes
Bond controls×Crisis					Yes
Adj. R^2	0.002	0.003	0.008	-0.028	-0.024
N of obs.	197016	197016	197016	195372	157038

Table 5: **Mutual fund ownership and yield spread during crisis**

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

Dependent variable: bond yield spreads (tax-adjusted)					
	(1)	(2)	(3)	(4)	(5)
Held by MF×Crisis	0.161***				
	(3.47)				
MF share×Crisis		0.313***	0.287***	0.346***	0.126***
		(3.45)	(3.21)	(3.94)	(4.02)
Held by MF	-0.071***				
	(-3.14)				
MF share		-0.077*	-0.146**	-0.212***	-0.036**
		(-1.77)	(-2.67)	(-3.30)	(-2.75)
Crisis	2.238***	2.269***			
	(6.26)	(6.18)			
Bond controls	Yes	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	Yes	
Type FE	Yes	Yes	Yes	Yes	
Sector FE	Yes	Yes	Yes	Yes	
State FE	Yes	Yes	Yes		
Date FE			Yes	Yes	
Issuer FE				Yes	
Rating×Date FE					Yes
Type×Date FE					Yes
Sector×Date FE					Yes
Issuer×Date FE					Yes
Bond controls×Crisis					Yes
Adj. R^2	0.468	0.468	0.703	0.730	0.752
N of obs.	197016	197016	197016	195372	157038

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

Dependent variable: bond yield spreads (tax-adjusted)				
	(1)	(2)	(3)	(4)
MF outflow	0.051**	0.046**	0.041**	0.049**
	(2.83)	(2.60)	(3.21)	(3.05)
MF share		0.218***	0.171***	0.189**
		(5.58)	(3.69)	(3.00)
Bond controls	Yes	Yes	Yes	Yes
Rating FE	Yes	Yes	Yes	
Type FE	Yes	Yes	Yes	
Sector FE	Yes	Yes	Yes	
State FE	Yes	Yes		
Date FE	Yes	Yes	Yes	
Issuer FE			Yes	
Rating×Date FE				Yes
Type×Date FE				Yes
Sector×Date FE				Yes
Issuer×Date FE				Yes
Adj. R^2	0.553	0.553	0.606	0.630
N of obs.	26996	26996	26394	21264

Table 7: **The aftermath of mutual fund fire sales: pricing effects**

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 October 1, 2019 to September 30, 2020 (excluding March and April of 2020). *PostCrisis* is a dummy variable that equals to one for the period of May 1 to September 30, 2020, and zero otherwise. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond Controls* × *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond state indicates which U.S. state the issuer is located at. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: Bond yield spreads (tax-adjusted)			
	(1)	(2)	(3)
MF share × Post-crisis	0.263***	0.203***	0.158***
	(9.49)	(8.28)	(9.12)
MF share	-0.085***	-0.104***	-0.082***
	(-3.92)	(-6.20)	(-7.42)
Bond controls	Yes	Yes	Yes
Rating × Month FE	Yes	Yes	Yes
Type × Month FE	Yes	Yes	Yes
Sector × Month FE	Yes	Yes	Yes
State × Month FE	Yes		
Issuer × Month FE		Yes	Yes
Bond controls × Post-Crisis			Yes
Adj. R^2	0.616	0.719	0.722
N of obs.	1417204	1399878	1399878

Table 8: **Mechanism of post-crisis pricing effects: bond liquidity**

The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from October 1, 2019 to September 30, 2020 (excluding March and April of 2020). For columns (1)–(2), the dependent variable is cumulative dealer inventory of individual municipal bond since October 1, 2019, in million dollars, winsorized daily at the top and bottom 0.5% levels. For columns (3)–(5), the dependent variable is normalized bid-ask spread measure of individual municipal bond, trimmed at the top and bottom 1% levels, and the sample is restricted to bonds more frequently traded over the sample period (e.g., $Freq > 30$ indicates that the subsample includes only bonds trade on more than 30 days over the sample period). *PostCrisis* is a dummy variable that equals to one for the period of May 1 to September 30, 2020, and zero otherwise. $MF\ share$ is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, and logarithm of amount outstanding (and logarithm of trading volume for first two columns). *Bond controls* × *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Dealer inventory		**Normalized bid-ask spread**		
			Freq>30	**Freq>45**	**Freq>60**
	(1)	(2)	(3)	(4)	(5)
MF share×Post-crisis	-0.746***	-0.449***	0.088*	0.159**	0.199*
	(-10.07)	(-6.39)	(1.82)	(2.06)	(1.70)
MF share	0.209***	0.054*	-0.243***	-0.282***	-0.258***
	(6.17)	(1.88)	(-6.37)	(-4.68)	(-2.93)
Bond controls	Yes	Yes	Yes	Yes	Yes
Bond controls×Post-crisis		Yes	Yes	Yes	Yes
Rating×Month FE	Yes	Yes	Yes	Yes	Yes
Type×Month FE	Yes	Yes	Yes	Yes	Yes
Sector×Month FE	Yes	Yes	Yes	Yes	Yes
Issuer×Month FE	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.109	0.116	0.440	0.459	0.476
N of obs.	1399878	1399878	70549	41475	24862

Table 9: **Mechanism of post-crisis pricing effects: run-risk channel (triple-difference approach)**

The dependent variable is tax-adjusted yield spread of municipal bonds, in percent. This bond-date sample includes only municipal bonds that are held by mutual funds, and spans from October 1, 2019 to September 30, 2020 (excluding March and April of 2020). 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), fund's average portfolio liquidity (proxied by credit rating, Columns 5–6), and fund's cash holdings (Columns 7–8), as of the most recent quarter-end (or most recent month-end for cash holdings, when available). $PostCrisis$ is a dummy variable that equals to one for the period of May 1 to September 30, 2020, and zero otherwise. $MF\ share$ is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. $Bond\ Controls \times PostCrisis$ indicates the interaction terms between the $PostCrisis$ dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond issuer is identified by the first 6 characters/digits of its CUSIP. p-$value\ of\ the\ difference$ indicates the p-value from testing the difference in the estimated coefficients on $MF\ Share \times PostCrisis$ across two subsamples. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	MF holders' Covid exposure		**MF holders' portfolio maturity**		**MF holders' portfolio liquidity**		**MF holders' cash holdings**	
	Large	Small	Long	Short	Low	High	Low	High
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
MF share×Post-crisis	0.196***	0.048*	0.224***	0.064***	0.202***	0.081***	0.324***	0.156***
	(5.18)	(1.67)	(5.75)	(2.83)	(5.37)	(3.17)	(6.04)	(2.82)
MF share	0.038	-0.004	0.045*	-0.037***	0.038	-0.024*	0.083**	0.042
	(1.36)	(-0.27)	(1.70)	(-3.05)	(1.43)	(-1.70)	(2.22)	(1.42)
Bond controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Bond controls×Post-Crisis	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rating×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Type×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Issuer×Month FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.763	0.736	0.754	0.787	0.758	0.746	0.778	0.798
N of obs.	310806	310443	310718	310337	311026	310349	141646	141230
p-value of the difference	0.003		0.000		0.009		0.038	

Table 10: **Testing alternative explanations**

The sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades). The dependent variable is tax-adjusted yield spread of individual municipal bond, in percent. For column (1), we exclude mutual-fund-held bonds that experience trading during the crisis period (March 9–20, 2020). For column (2), we exclude bonds whose total holding amount by mutual funds decreases from the end of 2019 to the end of 2020:Q1. The sample period for columns (1) and (2) spans from October 1, 2019 to September 30, 2020 (excluding March and April of 2020). For column (3), we include only muni bonds whose total holding amount by mutual funds is unchanged from the end of 2020:Q1 to the end of 2020:Q2. Column (4) further excludes bonds that are not held by any mutual funds at either of these two quarter-ends. The sample period for columns (3) and (4) spans from October 1, 2019 to June 30, 2020 (excluding March and April of 2020). *PostCrisis* is a dummy variable that equals to one for the period of May 1 to September 30, 2020, and zero otherwise. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond controls* × *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

	Dependent variable: bond yield spreads (tax-adjusted)			
	Slow recovery of fire sales?		**Reaching for yield?**	
	Excl. MF-held bonds traded during the crisis	Excl. bonds with reduction in MF holding over '20:Q1	Excl. bonds with MF holding change over '20:Q2	Incl. MF-held bonds without holding change over '20:Q2
	(1)	(2)	(3)	(4)
MF share×Post-crisis	0.103***	0.132***	0.203***	0.187***
	(0.000)	(0.000)	(0.000)	(0.000)
MF share	-0.074***	-0.095***	-0.148***	-0.018
	(0.000)	(0.000)	(0.000)	(0.185)
Bond controls	Yes	Yes	Yes	Yes
Controls×Post-crisis	Yes	Yes	Yes	Yes
Rating ×Month FE	Yes	Yes	Yes	Yes
Type×Month FE	Yes	Yes	Yes	Yes
Sector×Month FE	Yes	Yes	Yes	Yes
Issuer×Month FE	Yes	Yes	Yes	Yes
Adj. R^2	0.713	0.730	0.723	0.788
N of obs.	968261	1291998	831102	287247

Internet Appendix

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

Figure A.1: **Municipal bond yield spreads**

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. The sample period spans one year from October 1, 2019 to September 30, 2020. 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, those with insurance, and those with floating coupon rates.

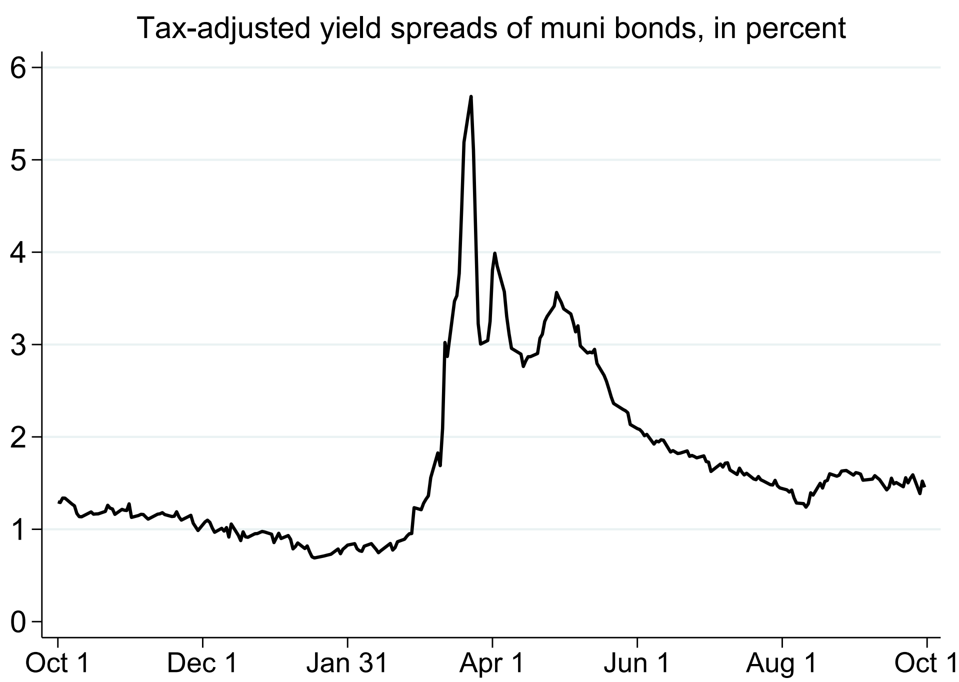

Table A.1: **The aftermath of mutual fund fire sales: pricing effects by subsamples**

The dependent variable is tax-adjusted yield spread of individual municipal bond, in percent. The full sample is at the bond-date levels and constructed from municipal bond trading data (excluding inter-dealer trades), spanning from October 1, 2019 to September 30, 2020 (excluding March and April of 2020). Columns (1)–(2) use subsamples defined by bond rating, with Column (1) including bonds rated as A, BBB, and high-yield, and Column (2) including bonds rated as AAA and AA. Columns (3)–(4) use subsamples defined by bond sector, with Column (3) including bonds in the sectors hit more by the Covid-19 crisis, including health& nursing, leisure, or transportation, and Column (4) including other bonds. Columns (5)–(6) use subsamples defined by bond type. *PostCrisis* is a dummy variable that equals to one for the period of May 1 to September 30, 2020, and zero otherwise. *MF share* is calculated as the share of mutual fund holdings of a municipal bond (as of the most recent quarter-end) relative to its outstanding amount. Bond controls include: coupon rate, age, time to maturity, logarithm of amount outstanding, and logarithm of trading volume. *Bond Controls* × *PostCrisis* indicates the interaction terms between the *PostCrisis* dummy and bond controls. Bond ratings include: AAA, AA, A, BBB, and high-yield. Bond types include: general obligation, revenue, and other. Bond sectors include: general, education, health & nursing, housing & development, leisure, public service, transportation, and utility. Bond issuer is identified by the first 6 characters/digits of its CUSIP. Standard errors are clustered at the bond and date levels, with corresponding t-values in parentheses. ***, **, and * indicate statistical significance at the 1%, 5%, and 10% level, respectively.

Dependent variable: bond yield spreads (tax-adjusted)						
	By bond rating		**By bond sector**		**By bond type**	
	Low (1)	**High** (2)	**Covid-hit** (3)	**Less affected** (4)	**non-GO** (5)	**GO** (6)
MF share×Post-crisis	0.260***	0.059***	0.216***	0.111***	0.191***	0.045**
	(7.30)	(4.14)	(5.14)	(6.83)	(9.06)	(2.06)
MF share	-0.074***	-0.066***	0.016	-0.087***	-0.082***	-0.061***
	(-3.36)	(-5.97)	(0.64)	(-7.76)	(-6.14)	(-3.62)
Bond controls	Yes	Yes	Yes	Yes	Yes	Yes
Bond controls×Post-Crisis	Yes	Yes	Yes	Yes	Yes	Yes
Rating×Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Type×Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Sector×Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Issuer×Month FE	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R^2	0.750	0.608	0.738	0.706	0.727	0.683
N of obs.	363401	1035893	269744	1129633	944884	453996