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Flight to Liquidity or Safety? Recent Evidence from the Municipal Bond Market

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Abstract

We examine how the COVID-19 pandemic and subsequent policy actions impacted municipal bond pricing through liquidity and credit risk channels. Focusing on narrow trading windows around each policy action, we find that announcements on fiscal policy and direct monetary policy interventions quickly reduced liquidity risk concerns in the municipal bond market. However, these actions didn't immediately ease credit concerns about municipal issuers. Using rolling-window regressions, we find that credit risks were an important component of short-term bond yields, but not for longer-term bonds, early on in the pandemic. Fiscal and monetary policy interventions successfully eased credit risk concerns for short-term bonds over time; but during the same period, longer-term bonds saw considerable increases in their credit risk premia. The shift in credit risk pricing from short-term to longer-term bonds over the course of the pandemic likely reflected policy intervention designs that primarily benefited short-term bonds, as well as investors' expectations of long-lasting recessional impacts on state and local government budgets.

Keywords: municipal bonds, credit risk, fiscal and monetary policy
JEL Codes: E52, E62, G12, H74

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1 Introduction

The COVID-19 pandemic delivered a sudden blow to the U.S. economy. In March 2020, the economic outlook deteriorated rapidly and investors fled risky assets as governments and individuals took preventative measures. Municipal bond yields increased sharply, potentially driven by both liquidity risks associated with the tightening of broad financial conditions and credit concerns on issuers' ability to service their bonds.

In response, the U.S. Congress and the Federal Reserve conducted a series of swift and unprecedented policy interventions in late March and early April. The Federal Reserve took a number of actions indirectly targeting the municipal bond market when they expanded liquidity facilities to accept municipal securities as collateral. Congress passed the Coronavirus Aid, Relief, and Economic Security (CARES) Act, which included appropriations to state and local governments, as well as funds to backstop new Federal Reserve facilities. The backstop funds allowed the Federal Reserve to set up a facility that provided direct support to municipal bond issuers.

In this paper, we focus on the following questions: Did the rising municipal bond yields at the onset of the pandemic reflect liquidity or credit risks? Did the series of policy interventions change how investors priced the two types of risks? On one hand, liquidity strains in the broad financial markets could have aggravated investors' concerns about their ability to liquidate municipal bond portfolios, contributing to municipal bond market selloffs. Therefore, policy interventions to support financial markets, as well as the broader economy, could stabilize municipal yields by easing aggregate liquidity risk concerns. On the other hand, the pandemic could represent a fundamental change to local economic conditions, raising concerns about the ability of municipal bond issuers to service their debt. Therefore, policy interventions that alleviate credit concerns can also stabilize the municipal bond market.

In order to separately identify the liquidity and credit risk channels, we use pre-refunded bonds as a control group to capture aggregate liquidity risks following Novy-Marx and Rauh [2012] and Schwert [2017]. For each pre-refunded bond, new refunding bonds are issued, and the proceeds are invested in Treasury securities and held in an escrow account. Since future payments on the underlying bond are fully covered by the escrow account's investment earnings, pre-refunded bond yields are affected by Treasury market movements, as well as liquidity concerns more broadly, but are very unlikely to be influenced by credit risks of bond issuers. In contrast, non-pre-refunded bonds are directly exposed to both issuer specific credit risks and aggregate liquidity risks. Therefore, movements in pre-refunded bond yields should reflect liquidity concerns, while changes in spreads between pre-refunded and not-pre-refunded bond yields should reflect credit risks. We compare the two types of bonds and study how the pandemic and the policy interventions impacted the municipal bond market through the liquidity and credit risk channels. In particular, we explore the impact of policy interventions both immediately following policy announcements and in the months after the interventions.

First, we study the impact of *each separate* policy intervention on the municipal bond market. To minimize the spillovers between policy changes, we employ a high-frequency identification strategy and focus on movements in municipal bond yields during narrow trading windows around policy announcements.[1] Specifically, we generate a sample of bonds that traded both before and after the announcement within a narrow window, and estimate the effect of each policy announcement on bond yields after controlling for a security-level fixed effect.

We find that announcements of policy interventions stabilized municipal bond yields significantly by lowering aggregate liquidity risks, but they didn't immediately ease credit concerns about municipal issuers. Specifically, both pre-refunded and non-pre-refunded municipal bonds saw significant declines in their yields immediately following news of the sweeping fiscal stimulus package. Monetary authority actions that directly intervened in the municipal bond market also reduced yields. For instance, following the passage of the CARES Act in the U.S. Senate, municipal yields made their biggest decline of more than 60 basis points, which accounted for close to 30 percent of the average municipal yield at the time. Similarly, the Federal Reserve's announcement of a dedicated municipal market lending facility that effectively provided an explicit backstop funded by the Treasury led to a decline of close to 20 basis points in average yields. On the other hand, indirect interventions by the monetary authority through money market mutual funds were largely effective in lowering yields for short-term bonds, but didn't have a notable impact on longer-term bonds. Importantly, we find that immediately following those policy announcements, there were no additional declines in yields of non-pre-refunded bonds compared to pre-refunded bonds. Therefore, news about policy interventions had little *immediate* impact

[1] Although the municipal market is relatively illiquid and investors tend to "buy and hold" during normal times, the municipal bond market saw elevated trading activities in March and April 2020 during the pandemic. As we show in Section 4 and Appendix F, the impact of policy interventions was immediate and significant.

on credit risk concerns in the municipal bond market.

Next, we extend the analysis horizon and study how the impact of the pandemic, as well as fiscal and monetary authority interventions, manifested through liquidity and credit risk channels over time. Specifically, we use a rolling-window regression to compare yields of pre-refunded and non-pre-refunded bonds between January and May 2020.

We find that credit risks were an important component for short-term non-pre-refunded bonds at the onset of the pandemic. Specifically, the credit risk premia on non-pre-refunded bonds increased sharply, by 40 basis points, from early to late March. This movement reflects the immediate impact, as well as the perceived temporary nature, of the pandemic on local budgets at the onset. On the other hand, credit risk premia for long-term non-pre-refunded bonds remained largely unchanged during the same period. Instead, yield increases in those bonds were almost entirely driven by liquidity concerns. The result reflects the expectation at the time that lockdown measures could contain the spread of the virus within a short period of time, even though financial conditions were rapidly deteriorating.

However, fiscal and monetary authority interventions, as well as the progress of the pandemic, changed how credit risks manifested in the municipal bond market. Those policy interventions successfully eased credit concerns for short-term bonds, as their credit risk premia against pre-refunded bonds saw a steady decline of 20 to 30 basis points throughout April and remained at a relatively low level in May. Between the end of March and May, however, credit risk premia for long-term non-pre-refunded bonds increased by 30 basis points. Longer-term credit concerns became more relevant as the pandemic continued to drag on and investors began to anticipate traditional recession dynamics would take hold. The steady increase in long-term credit risk premia also likely reflected the fact that policy interventions targeted the short-term municipal bond market, and didn't address long-run credit concerns for municipal issuers.

This paper has several implications for policymakers. First, our analysis highlights that at the peak of the crisis, announcements of decisive fiscal and monetary policy interventions reduced aggregate market risks immediately and significantly. Second, the presence of a dedicated lending facility, despite limited usage, was effective at holding down short-term borrowing rates. Access to short-term municipal debt allows state and local governments to smooth spending over revenue collection periods, and a well-functioning municipal bond market is important to the U.S. economy. In 2019, the state and local government sector accounted for 10.6 percent of U.S. GDP and 13 percent of total employment. On the other hand, credit risks remained a concern for longer-dated bonds, which is the primary way for state and local governments to raise funding for long-term capital investments [Marlowe, 2015].

The paper is closely related to several studies on the effects of COVID-19 on the municipal bond market and the impact of policy interventions.[2] In a closely related paper, Haughwout, Hyman, and Shachar [2021] focus on the eligibility changes in the Federal Reserve's lending facility on April 27, and explore the impact of that policy change on the municipal bond market. Our paper complements their study but differs in the following ways. First, we distinguish liquidity versus credit risks, and study how the pandemic and the policy interventions impacted the municipal bond market through the two distinct risk channels. Second, while they focus on the dedicated Federal Reserve lending facility, we study the impact of both fiscal and monetary policy actions over time. Bordo and Duca [2021] view the municipal bond market from a historical perspective by using monthly data, and find that the Federal Reserve intervention capped the growth of spreads by 5 to 8 percentage points. Li and Lu [2021] focus on how earlier mitigating policies, as well as the Federal Reserve's interventions, affected the demand for *new* municipal bonds, while we distinguish the credit and liquidity risk channels among actively traded, outstanding bonds. Fritsch, Bagley, and Nee [2021] investigate the impact of monetary policy interventions using Bloomberg's aggregate municipal yield curve, while we use bond trading at issuer levels. Li, O'Hara, and Zhou [2021] highlight the potential fragility risks posed by mutual funds to the municipal bond market during the COVID-19 pandemic.

Our study also contributes to the literature on municipal bonds and financial conditions of state and local governments. Focusing on municipal bond transactions in 2018:Q4, Novy-Marx and Rauh [2012] estimate the effect of state pension investment losses on state bond yields and quantify a sovereign default channel in the municipal bond market. Schwert [2017] examines the pricing of municipal bonds between 1998 and 2015 and finds that credit risk accounts for 74 to 84 percent of municipal bond spreads. Adelino, Cunha, and Ferreira [2017] find that municipalities' financial constraints can have a significant impact

[2]There is a rapidly growing literature on corporate debt and equity markets. For instance, prior studies have examined corporate debt markets [Boyarchenko, Kovner, and Shachar, 2020; D'Amico, Kurakula, and Lee, 2020; Gilchrist, Wei, Yue, and Zakrajšek, 2020; Haddad, Moreira, and Muir, 2020; Karger, Lester, Lindsey, Liu, Weill, and Zúñiga, 2020; Nozawa and Qiu, 2020; O'Hara and Zhou, 2020], equity markets [Baker, Bloom, Davis, Kost, Sammon, and Viratyosin, 2020; Ding, Levine, Lin, and Xie, 2020], banking stress [Acharya and Steffen, 2020; Li, Strahan, and Zhang, 2020], and the Paycheck Protection Program [Bartik, Cullen, Glaeser, Luca, Stanton, and Sunderam, 2020; Granja, Makridis, Yannelis, and Zwick, 2020].

on local employment and growth. In addition, our paper is related to the broad literature on the pricing of municipal bonds, see Harris and Piwowar [2006] and Green, Hollifield, and Schürhoff [2006] among others. Following this line of work, we use transaction-level data to study the pricing of municipal bonds during the COVID-19 pandemic.

The remainder of the paper is as follows. Section 2 discusses the COVID shock and associated financial stress in the municipal bond market since early March, as well as unprecedented policy interventions in March and April. Section 3 provides details on our data. Section 4 evaluates the immediate impact of announcement of each policy intervention on municipal bond market through liquidity and credit risk channels. Section 5 examines how the impacts of the pandemic and the policy interventions manifested over time. Section 6 concludes.

2 The COVID-19 Shock and Policy Interventions

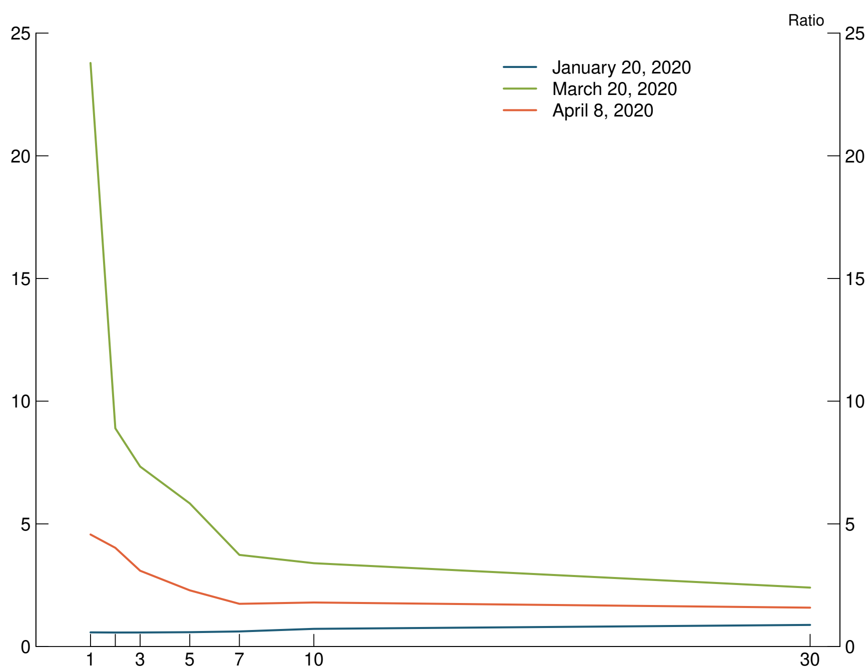
The COVID-19 pandemic dramatically slowed economic activities and triggered sell-offs in financial markets in March. In response, the U.S. Congress and the Federal Reserve undertook swift and unprecedented policy actions in late March and early April.

2.1 COVID-19 Shock

The first novel coronavirus case in the United States was reported on January 20, 2020 [Holshue, DeBolt, Lindquist, Lofy, Wiesman, Bruce, Spitters, Ericson, Wilkerson, Tural, Diaz, and Cohn, 2020]. From that date, case counts rose across the nation throughout February and early March. In mid-March, states began to issue quarantine and shelter-in-place orders, limiting permissible economic activities. Business revenues began to decline and unemployment increased sharply, representing a significant blow to state and local government revenues at a time when their spending was ramping up to fight the pandemic. The COVID shock also sparked broad concerns about financial market assets and intermediaries, as evidenced by the precipitous decline in prices of risky assets across the financial system. Municipal securities were not spared as investors moved to cash assets and the demand to hold municipal securities fell.

At the peak of the crisis, municipal bond market yields were extremely elevated, particularly for bonds with short remaining maturities. Yields on one-year maturity municipal securities rose 25 times higher than comparable maturity Treasury yields in mid-March as shown in Figure 1. Longer-dated bond yields also increased sharply and peaked at just around three times their comparable maturity Treasury yield levels. These moves represent significant increases in municipal yields, as they were slightly *lower* than Treasury yields across maturities just before the onset of the COVID pandemic. Moreover, the increase in yields was much more pronounced for bonds with shorter remaining maturities, leading to an inversion of the yield curve. The acute stress in the shorter end of the yield curve was in line with the immediate impact, as well as the perceived temporary nature, of the pandemic at the time.

Figure 1: Municipal Bond Yield to Treasury Yield Ratio



Source: Bloomberg.

2.2 Policy Interventions

In response to rapid deterioration in economic conditions and widespread stress in financial markets, the U.S. Congress and the Federal Reserve undertook unprecedented policy actions in late March and early April. These fiscal and monetary actions, however, were not taken simultaneously, but instead occurred in several stages that increasingly ratchet up market support.[3]

Policy interventions began with the Federal Reserve's rollout of a series of liquidity facilities, which were designed in similar ways as facilities utilized during the Great Financial Crisis. Through these programs, the Federal Reserve extended short-term loans by accepting high quality collateral. As the crisis intensified, the type and maturity of accepted collateral were broadened. On March 20, the Federal Reserve expanded the eligibility collateral for the Money Market Liquidity Facility (MMLF), which was established just days earlier to lend against certain short-term securities held by money market funds, to include highly rated, short-term municipal debt. On March 23, the MMLF eligible collateral was further expanded to include variable rate demand notes, a decision again aimed at the municipal bond market.[4]

On fiscal policy, the CARES Act passed both Congressional chambers in the last week of March, despite the rocky negotiations on the bill. On March 23, negotiations were deadlocked when Senate Democrats blocked a key procedural motion, leading to a downward spiral in financial market conditions. Following late-night negotiations, however, U.S. Treasury Secretary Steven Mnuchin and Senate minority leader Chuck Schumer emerged to announce they had a deal. As a result, the Dow Jones Industrial Average surged more than 11 percent on March 24, its biggest one-day gain since 1933. The CARES Act was ultimately approved by the Senate during a unanimous late-night vote on March 25 and, on March 27, the bill was passed by a near-unanimous vote in the House before being signed into law by President Trump.

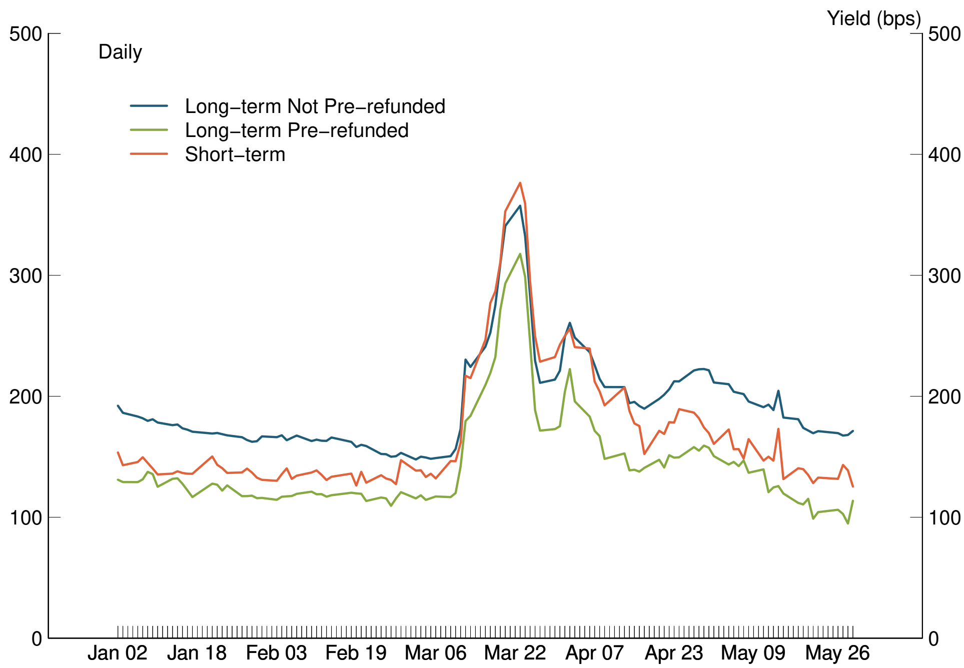
The CARES Act provided both direct and indirect supports to state and local governments. The unprecedented bill of $2.2 trillion expanded unemployment benefits and provided stimulus checks to households, issued grants and loans to small businesses, and funded COVID relief measures for state and local government. Many of these actions helped to relieve revenue and spending pressure from state and local governments, as they were desperately trying to contain a collapse of their local economies. In addition, the bill also appropriated funds to backstop facilities that could directly intervene in several key debt markets, including the municipal bond market. These facilities would be established by the Federal Reserve but capitalized by an equity stake owned by the U.S. Treasury.

[3] Appendix A provides a more detailed summary of Federal Reserve actions aimed at municipal bonds.

[4] On March 23, the Federal Reserve also published an updated term sheet for the Commercial Paper Funding Facility which clarified that U.S. municipal commercial paper issuers were eligible participants.

With equity funds appropriated from the CARES Act, the Federal Reserve Board announced the establishment of the Municipal Liquidity Facility (MLF) on April 9, providing $500 billion in loanable funds to municipal bond issuers. Under this program, the Federal Reserve could directly purchase new, short-term notes from eligible municipal bond issuers, who could then use the proceeds to support local jurisdictions under their authority.[5] By design, the MLF made the Federal Reserve a buyer of last resort in the municipal market– with losses backstopped by the Treasury's equity stake– and eased concerns about the ability of state and local governments to obtain short-term credit.

Figure 2: Trade-weighted Average Yields



Notes: Chart shows average yields weighted by trade amount for non-pre-refunded municipal bonds with remaining maturity of less than 1 year and more than 1 year, as well as pre-refunded municipal bonds. Source: Municipal Securities Rulemaking Board.

Following these monetary and fiscal actions, the municipal bond market stabilized sig-

[5] For example, a state could issue short-term bonds to the Federal Reserve and use those bond issuance proceeds to purchase the bonds of counties in the state.

nificantly, especially the short-term bond market. Figure 2 compares the trade-weighted average yields of non-pre-refunded bonds to those of pre-refunded bonds. While all pre-refunded bonds have remaining maturity longer than 1 year, non-pre-refunded bonds are split into two groups: those with remaining maturity less than 1 year (orange line), and those with more than 1 year of remaining maturity (blue line). Prior to the policy interventions, all three types of yields surged, with more pronounced increases for bonds with shorter remaining maturities. The passage of the CARES Act in late March led to steep declines in yields across all three types of bonds, while the Federal Reserve's announcement on the MLF program in early April had a more significant impact on shorter-dated municipal securities. Importantly, the spread on short-dated non-pre-refunded bonds against pre-refunded bonds narrowed significantly in April and May, while the spread on long-term non-pre-refunded bonds against pre-refunded bonds remained elevated. These dynamics suggest that monetary and fiscal policy interventions may have lowered credit risks for short-term bonds while easing liquidty stress across all bond types.

3 Municipal Bond Data

3.1 Overview of Municipal Bond Market

The municipal bond market is the primary way for state and local government units – such as counties, municipalities, and school districts – to raise funds. The public purpose and size of the municipal securities market underscores its importance in the U.S. economy.

State and local governments can issue short-term notes to bridge the gap between the time when expenses occur and when revenues become available, but the majority of municipal bonds are sold to finance long-term capital projects.[6] As documented in Marlowe [2015], approximately 90 percent of state and local capital spending is financed through municipal bonds. Therefore, municipal bonds typically have long-term maturities of between 1 and 30 years.

Municipal bonds are generally broken down into two major categories: general obligation (GO) bonds and revenue bonds. GO bonds are backed by the full faith and credit of the issuers, implying that all sources of revenue will be used to service the debt. Three quarters of local government tax revenues come from property taxes, while state govern-

[6] For instance, tax anticipation notes are issued in anticipation of tax receipts and are payable from those receipts. The maturities of those municipal short-term securities can vary from 3 months to 3 years, but usually mature within 12 months.

ments typically rely on sales and income taxes which account for close to 90 percent of their tax revenues. Revenue bonds, on the other hand, are generally issued to finance a specific revenue-generating project and secured solely by the revenues from that project. GO bonds, which are usually considered higher quality credits than revenue bonds, represent a larger proportion of the total municipal bond market. The MSRB reported that GO bonds accounted for 68 percent of trading activity in 2019.

Like other bond markets, the municipal bond market largely functions as an over-the-counter market, where investors place their orders with dealers directly rather than through a centralized clearinghouse. Currently, the MSRB reports that more than 1,200 dealers actively participate in trades. In addition, the municipal bond market has many issuers with many small issues. The current market consists of $3.8 trillion in outstanding bonds issued by more than 50,000 individual units of government.

The interest paid on most municipal bonds is exempt from federal income taxation. Bonds issued by entities domiciled in a particular state are typically exempt from taxation by that state, too. These tax exemption features make municipal bonds especially attractive to retail investors.

3.2 Data Source

Our analysis relies on secondary market transaction data reported to the MSRB between January 2 and May 29, 2020. The data collection records all inter-dealer and dealer-to-customer transactions on municipal GO bonds in real-time.[7] The data also include a range of information about the trades and underlying bonds as described in Appendix B. Following Novy-Marx and Rauh [2012], we focus on GO municipal bonds, as they are backed by the full faith and credit of issuers. In contrast, revenue bonds, typically secured by specific revenue streams, have a more idiosyncratic risk profile that is difficult to measure. Focusing on GO bonds improves identification because the credit risk is a function of the issuer's credit risk, rather than a combination of issuer and project credit risk. The raw files contain more than 1.44 million transaction records on more than 155,000 GO securities that were issued by more than 12,000 issuers.

We scrub the bond trade data of potentially problematic records and outliers, following cleaning steps similar as Schwert [2017] and Green, Li, and Schürhoff [2010]. First, we drop yields that are above the 99.5 or below the 0.5 percentiles, so as to remove unusual yields

[7] Transactions are reported to the MSRB with a 15 minute delay from the trade time.

that might be erroneously reported while still keeping the legitimately high yields during the peak stress period. Second, we remove records for U.S. territories and the District of Columbia as well as trades where the issuer state is missing. Third, we drop all trades that are recorded on a weekend or on a market holiday. Finally, we remove any trades with a maturity date prior to the trade date, or with missing trade dates, or having a value of zero for remaining maturity or principal amount. After these cleaning steps, our sample includes 1.38 million trades.

In order to analyze the data at a granular geographic level, we use a string parsing algorithm to determine each issuer's locality at the county level, or the state level if the issuer is a state government. The MSRB data doesn't directly provide counties associated with bond issuers; instead the locality information is embedded in the issuer name description. As detailed in Appendix C, we rely on a string parsing algorithm to extract the locality information. First, we determine whether the issuer is a state government by looking for the state name followed immediately by "state" or "st". For instance, "New York St" is the issuer name for the New York state government. Next, we search inside the remaining strings for county and city names. For instance, "Johnson Cnty Kans" is the issuer name for Johnson County, Kansas, while "Overland Park Kans" is the issuer name for the city of Overland Park in Johnson County, Kansas. Our county list is drawn from counties reporting COVID cases as tracked by the New York Times database and counties listed in the Census Bureau's TIGER/LINE shapefiles. For cities, we use a county to city crosswalk provided by the USPS to assign the county of the issuer to each record. We identify locality information for 90 percent of issuers and match 1.27 million observations, 20 percent of which were issued by state governments and the rest by counties and cities.

Finally, we match the transaction level data to ratings information from Moody's and S&P using the trade CUSIP. We also collect information on whether the bond is pre-refunded from Bloomberg. Schwert [2017] exploits within-bond changes in pre-refunded status using a long sample between January 1998 and June 2015 at monthly frequency. Since our data set covers only 5 months of trades and much of it is a severe stress period that hampered new debt issuance, we assume that the pre-refunded status isn't time varying. We pull pre-refunded indicators as of November 16, 2020 from Bloomberg. Details of pre-refunded bonds are discussed further in section 4.

3.3 Data Statistics

Table 1 reports summary statistics for the cleaned sample of daily municipal bond trades between January 2 and May 29, 2020. The average yield on securities in our sample is about 200 basis points and the average security has a remaining maturity of just over 9 years. The average principal amount of an issue is rather large at about $27 million, but it reflects a few very large issues since the median principal amount of an observed trade is less than $4 million. Similarly, the average traded amount in our sample is about $220,000 whereas the median traded amount is just $30,000. About 8 percent of bonds in our sample have remaining maturities under 1 year. According to the Moodys and S&P, only 4 percent of bonds are not rated. Within the rated bonds, 20 percent of them have ratings of AAA, 65 percent have AA, and the remainder are rated at A or below. Additionally, about 5 percent of our sample are pre-refunded bonds. Finally, about 20 percent of the trades were issued by states and another 20 percent were issued by county governments, with the remainder issued by municipalities, cities, or other sub-county levels of government.

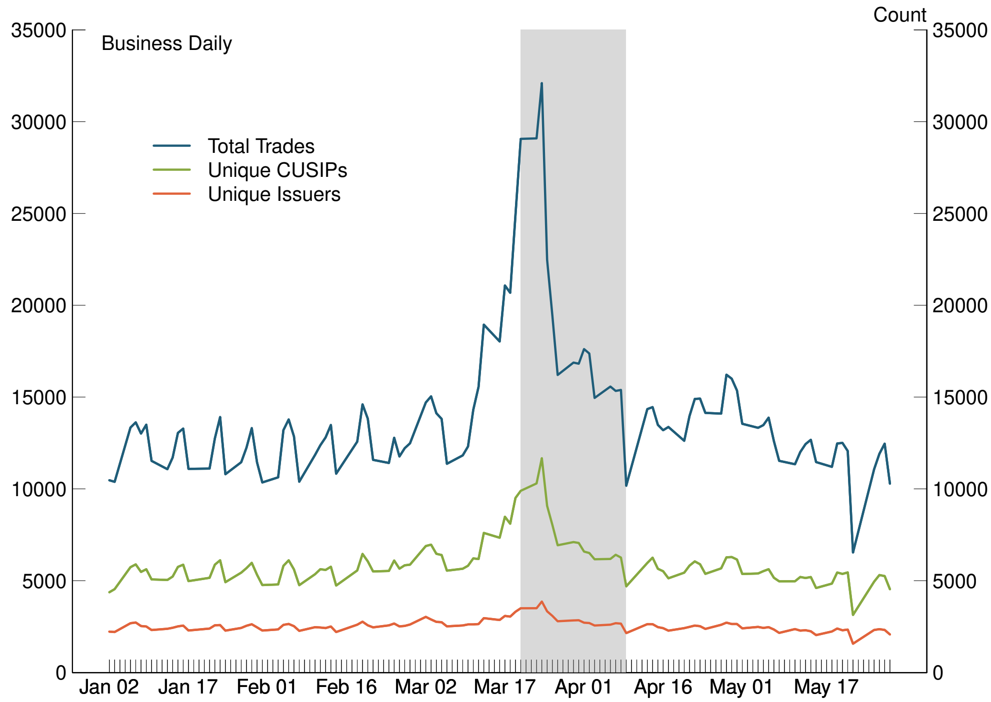
Table 1: Matched Sample Summary Stats

	Mean	Std. Dev	P25	P50	P75
Yield	199.821	91.948	127.700	185.000	249.300
Maturity (years)	9.163	7.147	3.342	7.501	13.471
Principal Amount ($ Millions)	27.277	205.350	1.185	3.715	14.765
Trade Amount ($ Millions)	0.220	1.331	0.015	0.030	0.100
Indicator Variable Averages					
Maturity < 1 year	0.080				
Ratings					
AAA	0.204				
AA	0.650				
A	0.079				
BBB	0.024				
BB	0.002				
B	0.000				
Below B	0.000				
Missing or Not Rated	0.040				
Pre-Refunded	0.047				
State Issuer	0.183				
County Issuer	0.234				
Observations	1,379,221				

Notes: Table presents summary statistics for the full sample matched to county or state issuers. P25, P50, and P75 represent the 25th, median, and 75th percentiles respectively. The variables not reporting percentiles are indicator variables. *State issuer* denotes observations issued by one of the 50 U.S. states. *County issuer* denotes obserations of bonds issued by U.S. counties. Remaining observations were issued by sub-county level entities.

Importantly, Figure 3 shows that trading activities were unusually elevated in late March. It suggests that investors were very likely to be attentive to news related to municipal bonds, and that policy interventions could have immediate impact on trading activities. Specifically, trading activity was stable in January and February, but increased sharply in March, peaking on March 24 with a record of over 30,000 transactions. Transaction counts returned to more normal levels following the swift policy interventions in late March. The numbers of uniquely traded bonds and of unique issuers followed a similar pattern. Appendix D provides additional evidence that the municipal bond market was under acute stress in late March.

Figure 3: Trade Count



Notes: Total trades are all trades reported in the MSRB transaction level dataset. Unique CUSIPs are the total number of CUSIPs traded within a single day. Unique issuers are the total number of six digit CUSIPs traded within a single day.
Source: Municipal Securities Rulemaking Board.

4 Immediate Impact of Policy Interventions

As discussed in Section 2, Congress and the Federal Reserve took swift and unprecedented policy actions to address municipal bond market stress. Different policy measures, however, may have had different impacts on liquidity and credit risks. The CARES Act provided direct support to the broad economy including funds for state and local governments. It also appropriated funds for the Federal Reserve to establish a liquidity facility that would directly purchase bonds from municipal issuers. At the same time, the Federal Reserve adopted a range of policy actions that operated indirectly through financial intermediaries, especially MMMFs, to reduce municipal bond market stress. The effectiveness of those actions may vary depending on whether they ease liquidity or credit risks, and how directly they intervened in the municipal market.

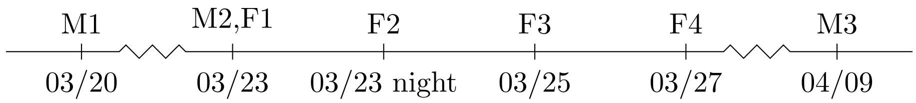
We estimate the immediate effect of *each* policy change, including legislative actions with impending fiscal support to the economy, as well as monetary policy announcements. On fiscal support, we use the news of key legislative benchmarks leading up to, and including, passage of the CARES Act. On monetary actions, we track actions taken by the Federal Reserve through their announcements on municipal debt related facilities, including the rollout of the MLF. In order to minimize the spillovers between policy changes, we conduct event studies with narrow trading windows.

Importantly, we study the channels through which each policy intervention impacted the municipal bond market *immediately* following the announcement. Specifically, following Novy-Marx and Rauh [2012] and Schwert [2017], we use pre-refunded bonds as a control group to capture aggregate liquidity risks. On one hand, liquidity strains in the broad financial markets could have contributed to municipal bond market sell-offs. Thus, news about policy interventions to support the broad economy could ease aggregate liquidity risks immediately, helping to stabilize municipal yields. On the other hand, the pandemic could raise credit concerns about the ability of municipal bond issuers to service existing debt, and some policy interventions could alleviate those credit risks. In this section, we focus on the immediate impact on municipal bonds following each policy announcement, while in section 5 we explore how those effects manifested over a longer period of time.

4.1 Event Studies with Narrow Trading Windows

Before estimating the immediate effect of each policy change, we lay out the timeline on fiscal and monetary policy interventions in late March and early April, as shown in Table 2. As laid out in Section 2, the legislative activities associated with the CARES Act were largely concentrated in the last week of March, while the Federal Reserve took a number of steps across the span of several weeks in late March and early April to address the stress in the municipal bond market.

Table 2: Timeline of Fiscal and Monetary Policy Interventions



M1: Federal Reserve's initial inclusion of municipal bonds in the MMLF (announced at 11AM ET);
M2: Federal Reserve's inclusion of variable rate demand notes as collateral in the MMLF (announced at 8AM ET);
F1: The Senate's failed procedural motions on the CARES Act;
F2: Mnuchin and Schumer reached agreement on the CARES Act (night);
F3: The Senate passed the CARES Act (night);
F4: The House passed the CARES Act; President signed into law;
M3: Federal Reserve's announcement on the MLF (announced at 8:30AM ET).

Using the real-time transaction data from the MSRB, we investigate each policy change within a narrow window around the announcement to minimize policy spillovers. As summarized in Table 3, we define the pre- and the post-event trades according to whether the trade occurred prior to the announcement or after, and generate a sample of bonds that traded both right before *and* right after each policy announcement. For example, municipal bonds were first included in the MMLF on March 20, 2020, and this change was announced at 11 AM ET in a Federal Reserve press release. We define the pre-event trades as those occurred on March 19, 2020 and before 11 AM ET on March 20, 2020. The post-event trades consists of those occurring after 11 AM ET on March 20, 2020. We limit the analysis to all bond CUSIPs that were traded in both the pre- *and* post-event periods.

The event study window is constructed in a similar way for other policy changes. At 8 AM ET on March 23, the Federal Reserve announced the inclusion of variable rate demand notes as eligible collateral in the MMLF. The trading window is set between March 20, the previous trading day, and March 23. One complication, however, is that on the same day, CARES Act negotiations were deadlocked when Democrats blocked a key procedural motion. Our estimate would reflect the joint impact from both policy developments. On the evening of March 23, the Treasury Secretary and the Senate minority leader reached an agreement on the CARES Act, and therefore the event window is set between March 23 and 24. The event windows are set between March 25 and 26 when the Senate passed the bill, and between March 26 and 27 when the House passed the bill.[8] Finally, at 8:30 AM

[8]Timiraos and Gillers [2020] reported on March 27, 2020 that the Federal Reserve Board were considering to set up a lending facility specifically aimed at state and local government finance and had hired a former Treasury official, Kent Hiteshew, to advise on municipal market issues. This news article may have had

ET on April 9, the Federal Reserve announced the establishment of the MLF program. The trading window for this event is set between April 8 and 9.

Table 3: Event Windows

Event	**Pre-event**	**Post-event**
MMLF Adds Muni Securities	March 19	March 20, 11:00 AM
MMLF Muni Terms Revised	March 20	March 23 8:00 AM
CARES Agreement In Principal	March 23	March 24
CARES Senate Passage	March 25	March 26
CARES House Approval; WH Signs	March 26	March 27
MLF Announcement	April 8	April 9 8:30 AM

Notes: All event windows end with the post-event sample trading day.

One potential concern is that an event study within a narrow window, as we conduct here, may not be suitable for the municipal market, as investors tend to hold municipal bonds over long periods and trading activity may not react to high-frequency news. While municipal securities typically involve infrequent trading during normal times, it was certainly not the case during the peak of the pandemic, as Figure 3 shows elevated trading activities in March and April 2020. During that period, Li et al. [2021] highlights that the majority of municipal market trading was not driven by retail investors, but rather tax-exempt money market funds who may be more attentive to related news. Furthermore, in section F, we follow the approach in Duygan-Bump, Parkinson, Rosengren, Suarez, and Willen [2013] and demonstrate that the Federal Reserve's intervention through the MMLF successfully reversed outflows for tax-exempt money market funds that qualified for the program. Therefore, news about policy interventions was very likely to be reflected in municipal bond yields during the unprecedented crisis.

It is also worthwhile to highlight that trades included in our event studies aren't systematically different from those excluded from our analysis, alleviating potential concerns on selection bias. Table E3 in Appendix E provides summary statistics for CUSIPs within each event window. For instance, for the initial policy announcement on the MMLF program, the third column shows that close to 36,000 trades were excluded from our event study, as those bonds were traded only before *or* after the policy announcement. On the other

some impact on the municipal bond market, but it is challenging to distinguish this event from the House passage of the CARES Act.

hand, close to 15,500 trades within the same window were included in the analysis as they were traded both before and after the announcement, as shown in the fourth column. The two groups weren't systematically different in terms of average yields. If anything, bonds included in our study may be slightly less risky than those excluded, as the included trades on average had a slightly higher investment grade share and also larger trading amounts, more typical of larger issuers. This observation holds for all event studies. Therefore, to the extent the sample tilts towards less risky bonds, our estimates should represent a lower bound in the effectiveness of policy interventions.

4.2 Immediate Impacts of Policy Interventions

We first study the immediate impacts of policy intervention announcements on municipal yields by using the regression specification as defined in equation (1).

$$yield_{b,t} = \beta_0 + \beta_1 I_t^{policy} + \gamma X_{b,t} + \eta_b + \varepsilon_{b,t} \tag{1}$$

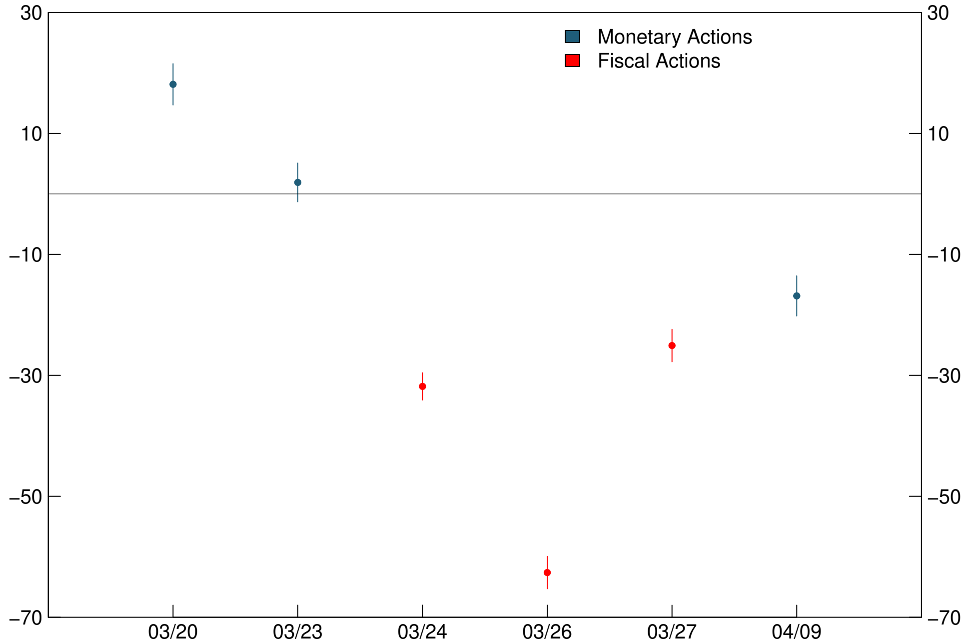
The dependent variable, $yield_{b,t}$, denotes the yield on bond b traded at time t.[9] I_t^{policy} is an indicator with a value of 1 for the period after the announcement and 0 before that. The vector, $X_{b,t}$, is a set of trade specific controls that includes the log of the trade amount and an indicator for whether the trade was a purchase or sale to a customer by the dealer. Crucially, we include a CUSIP level fixed effect, η_b, that absorbs all time invariant security characteristics. The fixed effect controls for risks at the security level, as well as demand for new funding at the issuer level, so long as these features are constant over the 2-day event window. The standard errors are clustered at the issuer level.

In terms of identification, this specification exploits *within* CUSIP variation, as we limit our sample to bonds that trade just before and just after the announcement. The coefficient of β_1 is the marginal effect of the policy intervention announcement on bond yields, conditional on the trade size and type, as well as the time-invariant security characteristics.

Turning to the estimation results, Congressional passage of the CARES Act had a significant impact in stabilizing the municipal bond market, as the estimates are highlighted in red in Figure 4. Yields on municipal securities declined following each policy development relative to their previous trading day. On March 25, the initial breakthrough on fiscal stimulus package reached between Mr. Mnuchin and Mr. Schumer lowered bond yields by

[9] In a robustness check (available in online appendix), we use the spread of municipal bond yields against Treasury yields of similar maturity as the dependent variable, and the estimation results remain unchanged.

Figure 4: Immediate Impacts of Policy Intervention Announcements on Municipal Bond Yields



Note: The plot shows estimated coefficients from a regression of traded municipal bond yields on an indicator for a monetary or fiscal policy intervention. The bond sample covers the day just prior to the intervention and the day of the intervention. Controls include CUSIP level fixed effects, log of the traded amount, and trade type. Interventions are: *3/20*: Acceptance of certain municipal bonds into the Federal Reserve's MMLF; *3/23*: an expansion of municipal bonds accepted to the MMLF; *3/24*: Agreement between Senate and Administration leaders on the CARES Act; *3/26*: Passage of the CARES Act through the U.S. Senate; *3/27*: Passage of the CARES Act through the U.S. House and Enactment; *4/9*: Announcement of the Federal Reserve's MLF.

32 basis points. On March 26, the unanimous passage in the Senate led to the largest decline of 63 basis points in yields, which accounted for close to 30 percent of the average municipal yields at the time. The final passage in the House on March 27 further reduced yields by 25 basis points. All the estimates are both statistically and economically significant. Cumulatively, the series of fiscal news lowered municipal yields by 120 basis points.

With monetary policy, Figure 4 shows that the MLF, the Federal Reserve's direct intervention in the municipal bond market with a credit backstop, was much more effective than earlier indirect interventions through the MMLF programs. The initial inclusion of municipal securities in the MMLF on March 20 failed to stabilize yields in general. On the following Monday, March 23, the terms of the MMLF were expanded to include certain variable rate demand notes. This policy announcement appeared to have an insignificant impact on municipal yields, but this estimate is likely to also reflect the deadlock in the CARES Act negotiations. In contrast, the announcement of the dedicated MLF facility on April 9 lowered yields by 17 basis points, in a similar range as the final passage of the CARES Act in the House.

The comparison across different monetary policy responses highlights that indirect policy intervention through the MMLF program had limited immediate success in reducing municipal yields *across maturities*. The MMLF program worked through money market mutual funds. In normal times, money market mutual funds accept municipal bonds as one type of collateral in exchange for short-term loans and do not require the Federal Reserve to make outright purchases of municipal debt. During the crisis, the backstop from the MMLF program could help to stabilize broad financial conditions, as we demonstrate that the MMLF program was successful in reversing funds outflows from the money market mutual funds in Section F. However, their effectiveness in the municipal bond market appeared more limited in general, while the announcement of the MLF, through which the Federal Reserve could directly purchase municipal bonds from issuers, was accompanied by an immediate decline in municipal yields. In the Section 4.4, we split municipal bonds across different maturities and demonstrate that indirect monetary policy actions were largely successful in stabilizing short-term yields.

4.3 Liquidity vs. Credit Risks

In this section, we study the channels through which policy interventions stabilized the municipal bond market. On one hand, liquidity strains in financial markets could have contributed to municipal bond market sell-offs. On the other hand, the pandemic also raised credit concerns about the ability of municipal bond issuers to service existing debt. It is important to understand how policy interventions reduced municipal bond yields through the liquidity and credit risk channels.

Following Novy-Marx and Rauh [2012] and Schwert [2017], we use pre-refunded bonds as a control group to capture aggregate liquidity risks. Pre-refunding is a common strategy for refinancing municipal bonds before their callable date (Chalmers [1998]). A bond is considered pre-refunded when new bonds, called "refunded" bonds, are issued with proceeds designated to service the existing bond. Specifically, with those proceeds, Treasury securities are purchased and deposited in an escrow account, which is structured to exactly mimic the interest payments of the "pre-refunded" bond. The pre-refunded bond is considered fully collateralized in the sense that the associated principal and interest payments are paid exclusively from the income derived from the escrow account.

To explore how policy interventions affect liquidity and credit risks, we include an interaction term between policy intervention and not-pre-refunded bond indicator I_i^{npre}, as specified in equation (2). Therefore, we compare yields on pre-refunded and non-pre-refunded bonds and see how they varied before and after policy interventions.

$$yield_{b,t} = \beta_0 + \beta_1 I_t^{policy} + \beta_2 I_t^{policy} I_b^{npre} + \gamma X_{b,t} + \eta_b + \varepsilon_{b,t} \tag{2}$$

Our identification crucially depends on the distinct funding schemes underlying pre-refunded and non-pre-refunded bonds. Pre-refunded bonds are fully collateralized with principal and interest payments being paid exclusively from their escrow accounts. As a result, they are exposed to risks associated with Treasury securities, but are very unlikely to be affected by credit risks associated with issuers. Non-pre-refunded bonds, however, are directly exposed to credit risks of bond issuers.

Table 4: Immediate Impacts of Annoucements of Policy Interventions: pre-refunded vs. non-pre-refunded bonds

	(1) Agreement	(2) Senate	(3) House	(4) MMLF	(5) MMLF Revised	(6) MLF
Intervention	-26.369***	-67.667***	-27.730***	3.915	3.469	-16.697***
	(3.909)	(4.721)	(4.400)	(6.464)	(8.579)	(6.236)
Intervention × Not Prerefunded	-5.715	5.255	2.815	14.937**	-1.672	-0.169
	(4.163)	(4.904)	(4.493)	(6.452)	(8.786)	(6.212)
Observations	18,277	10,800	9,502	15,451	15,971	5,875
Adjusted R^2	0.67	0.82	0.81	0.69	0.67	0.94

Notes: Each column represents an event study where the indictor *Intervention* takes the value of 1 for bonds traded after the intervention announcement. The sample is the day of the announcement and the day prior. Regressions include log of trade amount and indicators for trade type.
Issuer domicle state clustered standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Turning to estimation results, Table 4 highlight that announcements of policy interventions stabilized municipal yields by lowering liquidity risks, while they had little immediate impact on credit risks in the municipal bond market. As shown in column (1) to (3), news about CARES Act significantly reduced municipal yields on average. The interaction term between policy intervention and the not-pre-refunded bond indicator β_2, however, is insignificant throughout the passage of CARES Act, meaning there was no additional decline in yields of non-pre-refunded bonds when compared to pre-refunded bonds. Therefore, those policy development announcements stabilized the municipal bond market through lowering liquidity risks, but they didn't immediately ease credit concerns about municipal issuers. Column (4) to (6) show a similar finding for monetary policy interventions, as the interacted term is insignificant when the Federal Reserve announced an expansion to MMLF eligibility and when the MLF was launched. At the initial inclusion of municipal notes to the MMLF, the interaction term is even positive and significant, which likely reflects a deteriorating credit outlook at the beginning of the pandemic.

Since all pre-refunded bonds have maturity of more than 1 year, we provide a robustness check with narrower samples by excluding all bonds with maturity less than 1 year. Table 5 shows that the results are unchanged in this alternative case, when we only include non-pre-refunded bonds with similar maturities as pre-refunded bonds.

Table 5: Immediate Impacts of Annoucements of Policy Interventions: pre-refunded vs. non-pre-refunded longer-term bonds

	(1) Agreement	(2) Senate	(3) House	(4) MMLF	(5) MMLF Revised	(6) MLF
Intervention	-27.969***	-69.024***	-28.728***	2.266	3.158	-17.544***
	(3.982)	(4.741)	(4.477)	(6.570)	(8.633)	(6.360)
Intervention × *Not Prerefunded*	-2.545	7.037	5.348	18.254***	-1.358	0.890
	(4.184)	(4.884)	(4.516)	(6.546)	(8.799)	(6.328)
Observations	16,682	9,807	8,800	14,198	14,897	5,548
Adjusted R^2	0.70	0.84	0.85	0.72	0.69	0.95

Notes: The samples include bonds with remaining maturity of more than 1 year. Each column represents an event study where the indictor *Intervention* takes the value of 1 for bonds traded after the intervention announcement. The sample is the day of the announcement and the day prior. Regressions include log of trade amount and indicators for trade type.
Issuer domicle state clustered standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

4.4 Short- vs. Long-term Bonds

In this section, we further explore the immediate impacts of policy interventions by splitting samples into short- and long-term bonds. The CARES Act provided pandemic relief funds to state and local governments aimed at their near-term spending needs, and the Federal Reserve's interventions also targeted the short-term municipal bonds. Therefore, it is important to differentiate municipal bonds with different maturities.

As specified in equation (3), we include an interaction term between policy intervention and short-term debt indicator.

$$yield_{b,t} = \beta_0 + \beta_1 I_t^{policy} + \beta_2 I_t^{policy} I_b^{ST} + \gamma X_{b,t} + \eta_b + \varepsilon_{b,t} \quad (3)$$

The maturity indicator, I_b^{ST}, is a proxy for the maturity eligibility criteria for the Federal Reserve programs, and is assigned a value of 1 for securities with remaining maturities that meet the eligibility cutoff and 0 otherwise. The MMLF program only accepted securities with remaining maturity of 12 months or less, and the maturity eligibility criteria for the MLF program is two years or less.[10] We explore both 1 year and 2 year remaining maturity cutoffs in our analysis. The coefficient of β_1 is the marginal effect of the announcement on longer-term security yields, while $\beta_1 + \beta_2$ is the marginal effect on short-term bond yields.

Table 6: Immediate Impacts of Announcements of Federal Reserve Interventions: Short- vs. Long-term Bonds

	(1) MMLF	(2) MMLF	(3) MMLF Revised	(4) MMLF Revised	(5) MLF	(6) MLF
Intervention	20.832***	22.086***	2.402	2.578*	-16.212***	-15.547***
	(1.742)	(1.718)	(1.529)	(1.513)	(1.596)	(1.584)
Intervention × One Year Debt	-34.448***		-7.378		-12.321	
	(8.186)		(9.781)		(10.916)	
Intervention × Two Year Debt		-24.417***		-4.560		-10.593*
		(4.985)		(5.731)		(5.680)
Observations	15,451	15,451	15,971	15,971	5,875	5,875
Adjusted R^2	0.69	0.69	0.67	0.67	0.94	0.94

Notes: Each column represents an event study where the indictor *Intervention* takes the value of 1 for bonds traded after the intervention announcement. The sample is the day of the announcement and the day prior. Regressions include log of trade amount and indicators for trade type.
Issuer domicle state clustered standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Starting with monetary policy, Table 6 shows that interventions from the Federal Reserve were largely successful in lowering yields for short-term bonds. Columns (1) and (2) show that the initial inclusion of municipal securities in the MMLF was accompanied by higher yields on longer-term municipal bonds; but compared to those longer-term bonds, bonds with remaining maturity of less than one or two years declined by 25 to 35 basis points. Overall, the initial intervention through MMLF slightly lowered the yields of short-term bonds, which were the policy target, as shown by $\beta_1 + \beta_2$. Similarly, the extended MMLF intervention also lowered the short-term yields, but the impact wasn't statistically significant, which is likely to reflect the deadlocked CARES Act negotiations in Congress.

[10]The MLF maturity eligibility was later expanded to 36 months on April 27.

Finally, the announcement of the MLF on April 9 lowered yields for long-term bonds by 16 basis points and for short-term bonds by 25 basis points.

Table 7: Immediate Impacts of Announcements of Fiscal Policy Interventions: Short- vs. Long-term Bonds

	(1) Agreement	(2) Agreement	(3) Senate	(4) Senate	(5) House	(6) House
Intervention	-29.170***	-26.681***	-61.315***	-60.273***	-22.689***	-21.905***
	(1.060)	(1.047)	(1.311)	(1.455)	(1.263)	(1.333)
Intervention × *One Year Debt*	-31.585***		-14.310**		-31.005***	
	(6.244)		(6.548)		(9.873)	
Intervention × *Two Year Debt*		-29.528***		-13.074***		-18.764***
		(3.650)		(3.760)		(4.913)
Observations	18,277	18,277	10,800	10,800	9,502	9,502
Adjusted R^2	0.68	0.68	0.82	0.82	0.82	0.82

Notes: Each column represents an event study where the indictor *Intervention* takes the value of 1 for bonds traded after the announcement. Regressions include log of trade amount and indicators for trade type.
Issuer domicle state clustered standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Turning to fiscal policy interventions, the passage of the CARES Act led to significant reductions in yields for short-term bonds, as shown in Table 7. The agreement on fiscal stimulus package between Mr. Mnuchin and Mr. Schumer lowered long-term bond yields by close to 30 basis points, and shorter-term bond yields by 55 to 60 basis points as shown by the estimates of $\beta_1 + \beta_2$ in column (1) and (2). The unanimous passage in the Senate reduced long-term bond yields by 60 basis points, and short-term yields by more than 70 basis points. Finally, the passage in the House reduced yields for longer-term municipal bonds by more than 20 basis points and for short-term bonds by 40 to 50 basis points. Those estimates are statistically and economically significant.

Taken together, when focusing on a narrow trading window around policy announcements, we find that fiscal policy interventions, as well as direct monetary policy interventions with a backstop, had a significant and immediate impact in stabilizing municipal bond yields. Indirect monetary policy interventions that operate through financial intermediaries were largely successful in lowering yields for short-term bonds, while their impacts on long-term bonds were limited. Importantly, we find that within a narrow window, those policy announcements stabilized the municipal bond market through lowering liquidity risks rather than alleviating credit concerns about municipal issuers.

5 Impact of Policy Interventions Over Time

We next explore how policy interventions affect the municipal bond market through liquidity and credit risk channels over a longer period of time. In the previous section, we estimated the immediate impact of policy announcements by focusing on a narrow window. However, it may take time for policy interventions to play out and for investors to fully price in policy changes. In this section, we consider fiscal and monetary policy interventions jointly and estimate how their impacts manifest over a longer period of time.

5.1 Rolling-window Regression

To explore liquidity and credit risk channels over time, we compare yields on pre-refunded and non-pre-refunded bonds by using a rolling-window regression as shown in equation (4).

$$yield_{i,t}(n) \quad = \quad \alpha_{c,t}(n) + \beta_t I_i^{npre}(n) + \gamma X_{i,t}(n) + \varepsilon_{i,t}(n) \tag{4}$$

The rolling window width is n trading days. The dependent variable is the yield on municipal bond i by an issuer in county c of state s that was traded on day t. I_i^{npre} is the indicator for non-pre-refunded bonds. The vector, $X_{i,t}$, is a set of bond specific controls that includes the remaining maturity, the log of the trade amount, the log of principal amount, and indicators for trade type and bond ratings. We also include a county-time fixed effect, and therefore compare the yields on traded bonds within counties on the same day. These fixed effects pick up time-varying changes at the county level that may affect both pre-refunded and non-pre-refunded bonds. Standard errors are clustered at the state level.

As with the event studies, our identification crucially depends on the distinct funding schemes underlying pre-refunded and non-pre-refunded bonds. Most notably, pre-refunded bonds do not have credit risk while non-pre-refunded bonds do. Therefore, β_t represents the credit risk premia that investors charge on non-pre-refunded bonds over pre-refunded bonds during the rolling window, after controlling for county fixed effect and bond specific effects.

Turning to the estimation results, Figure 5 shows that the estimated path of β_t with a rolling window of one day.[11] First, the credit risk premia of non-pre-refunded bonds

[11] The message remains the same when we consider longer rolling windows. The online appendix provides estimations with $n = 7$.

over pre-refunded bonds, as measured by β_t, were positive and significant throughout the sample, as non-pre-refunded bonds aren't secured by Treasury securities in escrow accounts. Second, the premia were largely stable from January to early April, fluctuating between 40 to 50 basis points. This suggests that even though municipal bond yields surged rapidly in late March at the peak of the crisis, at the time investors didn't price in higher credit risks in municipal bonds *on average across maturities*. By aggregating municipal bonds across maturities, however, this regression masks potentially distinct impacts of the pandemic on short- versus longer-term bonds.

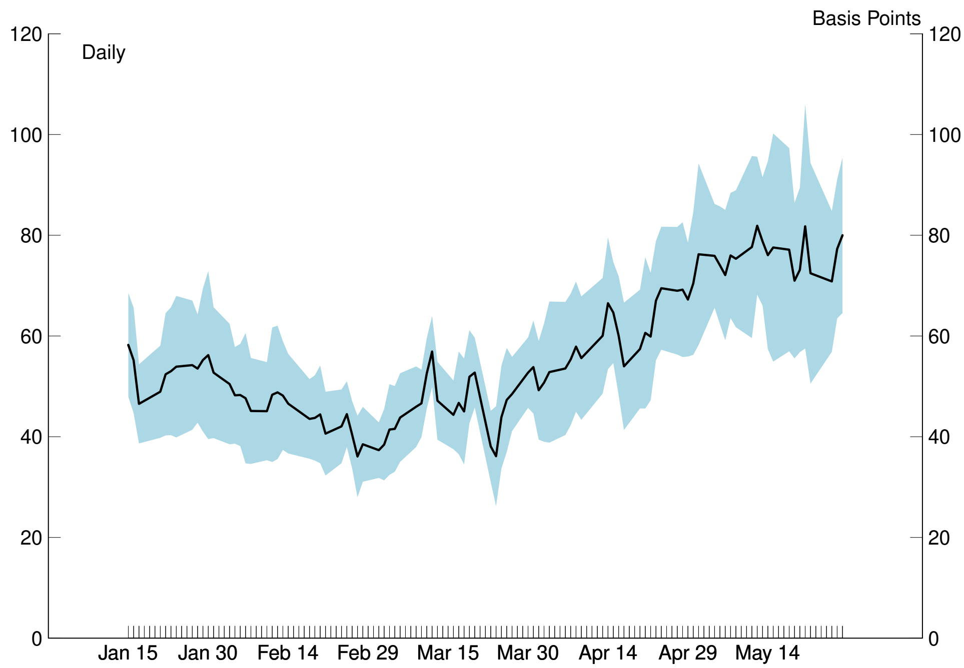
Importantly, it is notable that the premia increased in April and reached close to 80 basis points in May. While this is puzzling at first glance, the result suggests that investors priced credit risks of longer-term, non-pre-refunded municipal bonds relatively higher following joint monetary and fiscal policy interventions in late March and early April. As we will show below, bond maturity plays a key role in explaining this puzzling finding because policy interventions largely targeted short-term municipal bonds rather than longer-term securities.

5.2 Liquidity- vs. Credit Risks across Maturities

As the pandemic accelerated, municipal bond yields increased sharply in late March, especially for short maturity debt. Policy interventions helped to stabilize financial conditions broadly, reducing liquidity risks. Some of those policy measures also eased concerns on credit risks. Importantly, the Federal Reserve's interventions targeted the short-term municipal bonds, and the CARES act also provided pandemic-related relief funds to state and local governments that focused on the near-term spending needs. In this section, we study how policy impacts on municipal bonds with different maturities evolved over time.

We estimate the rolling-window regression with $n = 1$, as specified in equation (4), by splitting the non-pre-refunded bonds into two groups: short-term bonds with remaining maturity no longer than 1 year, and long-term bonds with remaining maturity longer than 1 year. In the first case, we *exclude* long-term non-pre-refunded bonds, and therefore compare short-term non-pre-refunded bonds with pre-refunded bonds after controlling for remaining maturity and other bond specific fixed effects. The estimated β_t is shown in Figure 6. In the second case, we limit the comparison between long-term non-pre-refunded bonds and pre-refunded bonds by *excluding* short-term non-pre-refunded bond. The estimated β_t is shown in Figure 7.

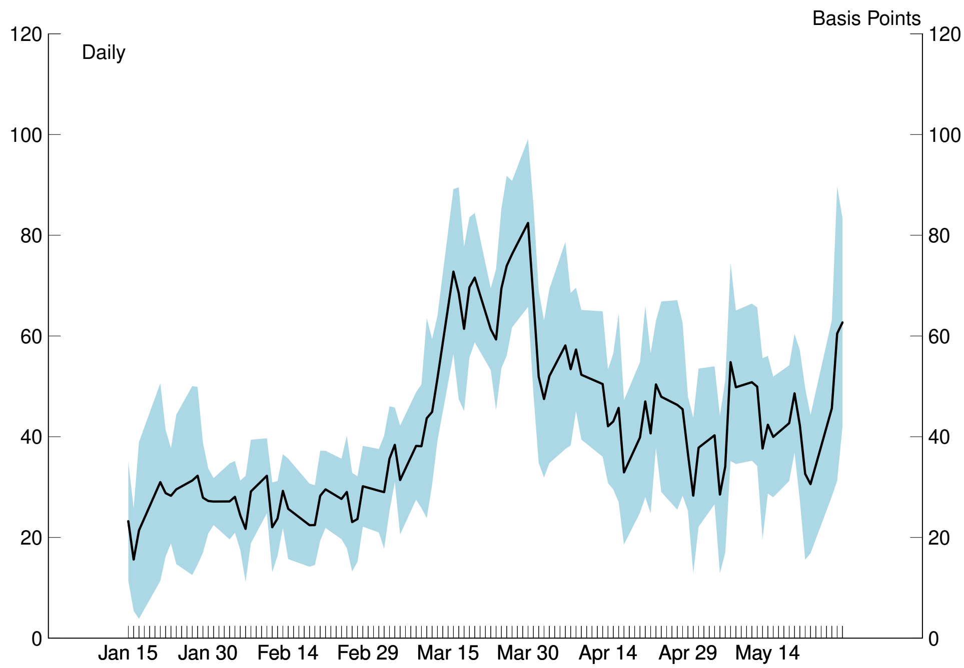
Figure 5: Rolling Window Regressions: Non-pre-refunded Bonds



As shown in Figure 6, the credit risk premia associated with short-term non-pre-refunded bonds increased sharply from mid to late March, rising from 30 basis points to 70 basis points during the peak of the crisis. Credit risks were an important component for short-term debt, given the immediate impact, as well as the perceived temporary nature, of the pandemic in the Spring of 2020. Measures such as quarantines and shelter-in-place mandates significantly lowered revenue forecasts for state and local governments and increased the risk that municipal bond issuers would be unable to meet their obligations in the near term.

In addition, the credit risk premia for short-term non-pre-refunded bonds remained an the elevated level in late March as a series of fiscal and monetary policy interventions was announced. This is consistent with the event studies in Section 4, which shows that within a narrow trading window, those policy announcements had very limited immediate impact on credit risks. However, those policy interventions successfully eased credit concerns over

Figure 6: Rolling Window Regressions: Non-pre-refunded Short-term Bonds

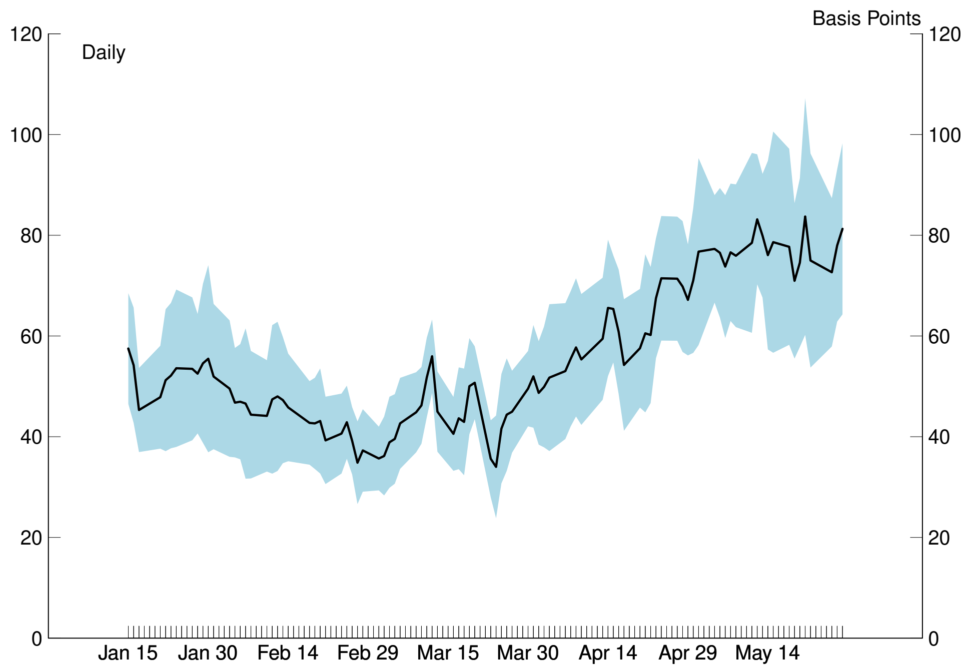


time. The credit risk premia saw steady declines throughout April by 20 to 30 basis points, and remained at the lower level in May.

In contrast, Figure 7 shows that the pandemic and the policy interventions had a drastically different impact on credit risks for long-term non-pre-refunded bonds. The credit risk premia were largely stable from January to early April: it narrowed somewhat in February, declining from 50 to 40 basis points, and then increased by a similar amount in March during the peak of crisis. Compared to the short-term non-refunded bonds as shown in Figure 6, changes in credit risk premia for long-term bonds were small at the peak of the crisis. In the Spring of 2020, lockdown measures were taken in the hope that the spread of the virus would be contained within a short period of time, and normal economic activities would be resumed. Therefore, investors were less concerned about credit risks associated with long-term bonds at the onset of the pandemic.

However, credit risk premia for long-term bonds increased steadily throughout April

Figure 7: Rolling Window Regressions: Non-pre-refunded Long-term Bonds



and May, reaching 80 basis points by the end of our sample compared to 50 basis points in the pre-pandemic level. The increase in credit risks in the longer-term bonds likely reflected two factors. First, as the pandemic continued to drag on and investors began to anticipate traditional recession dynamics, those long-term credit concerns became more relevant. Therefore, investors turned their focus to long-run credit concerns, in line with not a financial panic, but a more bread-and-butter recession dynamic which was expected to follow the pandemic. Second, the establishment of the MLF, a joint effort by the Federal Reserve and the Treasury, provided a way for municipalities to issue short-term bonds, even if the demand for new issuance was low in the private market. Nevertheless, the MLF program didn't address long-run credit concerns for municipal issuance.

For a robustness check, we use spreads between municipal bond yields and the comparable Treasury yields, instead of municipal yields, as the dependent variable. The alternative specification helps to control for the comparison between different maturities, since all pre-refunded bonds in our sample have remaining maturity longer than 1 year. The results remain unchanged, as shown in the online appendix.

Overall, the comparison between figures 6 and 7 highlights that the impacts of pandemic and policy interventions on short-term bonds are drastically different from those on long-term bonds. At the onset of the pandemic, near-term credit risks associated with shelter-in-place mandates and involuntary social distancing weighed on short-term, but not on long-term yields. Policy interventions successfully eased credit risks for short-term bonds by directly purchasing municipal bonds in the primary market and providing pandemic-related relief funds to state and local governments. However, long-run credit concerns became more prominent as the hope for a quick economic rebound were dashed and investors embraced a slower recovery.

5.3 Credit Risks across Ratings

Lastly, we explore how credit risk pricing changed across bond ratings. As shown in equation (5), we regress the pricing measure of bond i on its non-pre-refunded status, its rating, and also a policy intervention indicator. We interact these indicators to give a triple-difference model. The triple interaction tells us within the non-pre-refunded bonds, how pricing on lower rated bonds changed after the MLF was announced, compared to bonds that are more highly rated.

$$\begin{aligned} p_{i,t} \quad = \quad & \alpha_{s,t} + \beta_1^r I_i^{rate} + \beta_2^{rm} I_i^{rate} \times I_t^{policy} \\ & + \beta_1^n I_i^{npre} + \beta_2^{rn} I_i^{rate} \times I_i^{npre} + \beta_3 I_i^{rate} \times I_i^{npre} \times I_t^{policy} \\ & + \gamma^c X_{c,t} + \gamma^i X_{i,t} + \varepsilon_{i,t} \end{aligned} \tag{5}$$

Specifically, we use the bond yields, as well as the spread between municipal bond yields against comparable Treasury yields, as the dependent variable $p_{i,t}$. The policy indicator I_t^{policy} is 1 for periods after the MLF was announced and 0 otherwise. The rating dummy is 1 for bonds with ratings lower than a certain threshold. We explore two types of rating threshold: BBB and below, or A and below. In general, the BBB rating is the lowest rated class of municipal bonds, as there are very few bonds rated below that level. We also categorize bonds that are not rated under the rating threshold, as issuers may choose not to get a rating if they are more likely to receive a poor rating.

In addition to state-time fixed effect, we also include county-level controls, including

COVID cases per 100 residents, hospitals per 1000 residents, and the share of COVID affected employment. Specifically, we pair the MSRB transaction data with several data sets on local pandemic measures.[12] Daily county COVID case totals are from the *New York Times*, and the total number of hospitals per county level are from the Department of Homeland Security.[13] Using county population totals in 2019 from the Census Bureau, we derive per-capita measures for both COVID-19 cases and the number of hospitals. In order to capture the possible impact of the pandemic on local economies, we calculate the share of employment that was most affected by the COVID-19 shock. Following Boyarchenko et al. [2020], we calculate national employment growth from January to April at the 3-digit NAICS level using the Bureau of Labor and Statistics' Current Employment Statistics. Industries in the bottom quartile are considered the most affected. We then take these 3-digit industry codes and calculate the share employment in these affected sectors for each county as of 2019:Q4 using the BLS' Quarterly Census of Employment and Wages.

As shown in Table 8, we find that in general bonds that are not pre-refunded had higher yields and spreads across the whole sample, as investors demanded to be compensated for credit risks. We also find that bonds with lower ratings had higher spreads.

Following the introduction of the MLF, spreads on pre-refunded bonds declined more than those of non-pre-refunded bonds as shown by the positive and significant coefficients in the fourth row of the table. It indicates that interventions did not completely remove all credit risks. Importantly, among the non-pre-refunded bonds, we find that more poorly rated bonds were priced lower than better rated bonds, as indicated by their higher yields and spreads in the triple interaction term in the last row.

However, this impact was limited to very poorly rated bonds at investment grade or below. In columns (3) and (4), we expand the indicator for low rated bonds to include bonds rated A or below. We find that while the coefficients are still positive, only the spread is statistically significant. It highlights that only those bonds with the most credit risk relative to the market experienced more costly credit conditions following the intervention.

[12]County-level data are paired using our county of issuer match. In addition, we pair state-level demographic and economic data using the issuer's state domicile provided by MSRB, and we flag CUSIPs issued by state and county governments.

[13]Reported dates in the *New York Times* data are as-of the end of the previous day so these can be considered lagged case counts. For periods when no cumulative cases are reported for a jurisdiction, we set the case count to zero.

Table 8: Post-Intervention Credit Pricing

	BBB and Lower		A and Lower	
	(1)	(2)	(3)	(4)
	Yield	Spread	Yield	Spread
Not Prerefunded	49.610***	48.380***	47.564***	46.334***
	(5.002)	(4.970)	(4.632)	(4.554)
Rating	20.591***	19.925***	4.862	4.005
	(6.313)	(6.765)	(5.494)	(4.929)
Not Prerefunded × *Rating*	52.373***	47.287***	31.756***	29.856***
	(12.479)	(13.217)	(9.101)	(8.710)
Not Prerefunded × *MLF*	14.590***	16.957***	14.442***	16.447***
	(1.927)	(1.930)	(2.104)	(2.108)
Rating × *MLF*	-0.209	-0.813	6.203	4.970
	(14.197)	(13.749)	(7.701)	(7.274)
Not Prerefunded × *Rating* × *MLF*	41.770***	47.263***	11.694	16.208**
	(14.402)	(13.793)	(8.347)	(7.547)
Observations	926,898	926,898	926,898	926,898
Adjusted R^2	0.62	0.73	0.60	0.72

Notes: Sample is bonds traded between January 2, and May 29, 2020. MLF denotes the Federal Reserve's post Municipal Liquidity Facility announcement period defined as dates on or after April 9, 2020. Regressions include bond characteristics as well as issuer state domicile by trade date fixed effects. County level controls include covid cases per 100 residents, hospitals per 1000 residents, and share of COVID affected employment. Bond controls include log of trade amount, log of principal amount, log of remaining maturity, and an indicator for trade type. Standard errors clustered by issuer domicile state and trade date.

Clustered standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

6 Conclusion

We examine how the COVID-19 pandemic and subsequent policy actions impacted municipal bond market pricing through liquidity and credit risk channels. Focusing on narrow trading windows around each policy action, we find that announcements on fiscal policy and direct monetary policy interventions reduced liquidity risk concerns and helped quickly stabilize the municipal bond market. However, these actions didn't immediately ease credit concerns about municipal issuers.

Next, using rolling-window regressions to explore the longer-term impact of these actions, we find that credit risks were an important component of short-term bond yields early on in the pandemic, but did not affect longer-term bond yields. Fiscal and monetary policy interventions successfully eased credit risk concerns for short-term bonds over time, but during the same period, longer-term bonds saw considerable increases in their credit risk premia. The shift in credit risk pricing from short-term to longer-term bonds over the course of the pandemic likely reflected policy intervention designs that primarily benefited short-term bonds, as well as investors' expectations of long-lasting recessional impacts on state and local government budgets.

A Descriptions of Federal Reserve Programs Affecting U.S. Municipal Markets

Table A1: Dates and Descriptions of Federal Reserve Programs

Program	Date	Program Action	Details
MMLF	03/20	MMLF will accept highly rated municipal debt with remaining maturity not exceeding 12 months purchased from prime, single state, and other tax exempt funds as collateral from U.S. depository institutions, BHCs, and branches and agencies	Link
CPFF	03/23	CPFF will purchase highly rated 3-month U.S. dollar denominated commercial paper issued by eligible issuers, including municipalities, from CPFF dealers. Issuers must have issued new debt to non-sponsoring institutions between March 16, 2019 and March 16, 2020	Link
MMLF	03/23	MMLF will accept highly rated variable rate demand notes with features allowing holders to tender the note within 12 months	Link
MLF	04/09	MLF will purchase tax, tax and revenue, and bond anticipation notes or other short dated issues with maturity of 24 months or less issuers. Eligible issuers are states and D.C., cities with populations of more than 1 million residents, and counties with populations of 2 million residents.	Link

Notes: CCPF is the Commercial Paper Funding Facility. MMLF is the Money Market Mutual Fund Liquidity Program, MLF is the Municipal Liquidity Facility.

B MSRB Data Item Descriptions

Table B2: MSRB Transaction Data Items

Variable	Description
CUSIP	CUSIP of issue traded
Trade type	Customer purchase/sale, inter-dealer transaction
Trade date	Date trade was effected
Trade time	Time of trade execution
Dated date	Date of issuance
Settlement date	Date trade was settled
Maturity date	Maturity date of issue
Interest rate	Interest rate of issue
Yield	Yield-to-maturity
Issue description	Description of issue traded
Issuer name	Description of issuer
State	Issuer state
Seller/buyer ID	Dealer ID
Trade amount	Trade dollar amount
Principal amount	Principal dollar amount at issuance

C Determining County and State-Issuers

We determine county and state issuers using the following method:

1. We clean the issuer name provided by the MSRB by lower casing the name, dropping punctuation and special characters, and replacing abbreviations for words such as saint, mount, road, etc. We use the algorithm from Cohen, Friedrichs, Gupta, Hayes, Lee, Marsh, Mislang, Shaton, and Sicilian [2018].

2. For state issuers, we look for combinations of the issuer's domiciled state as reported by the MSRB and the word "st" or "state" in the issuer name.

3. For county issuers, we search for names of counties reported in the COVID data. Most counties are followed by strings such as "cnty" or "cntys".

4. For the remaining unmatched issuers, we look for cities names reported in the USPS county-city crosswalk.

5. When issuers match to both county and city names, we use the county name if we find "cnty" in the issuer name. Otherwise we use the county associated with the city match.

6. We allow for multiple matches in the case of jointly issued bonds. For multiple county matches, we set the county as missing. For multiple city matches, we set the county as the county of the cities if they are in the same county. Otherwise, we set the county to missing.

7. For certain cases our algorithm can't catch, such as determining between sets of cities or a single city, such as "bethel park, PA", we had assign a county after manually reviewing.

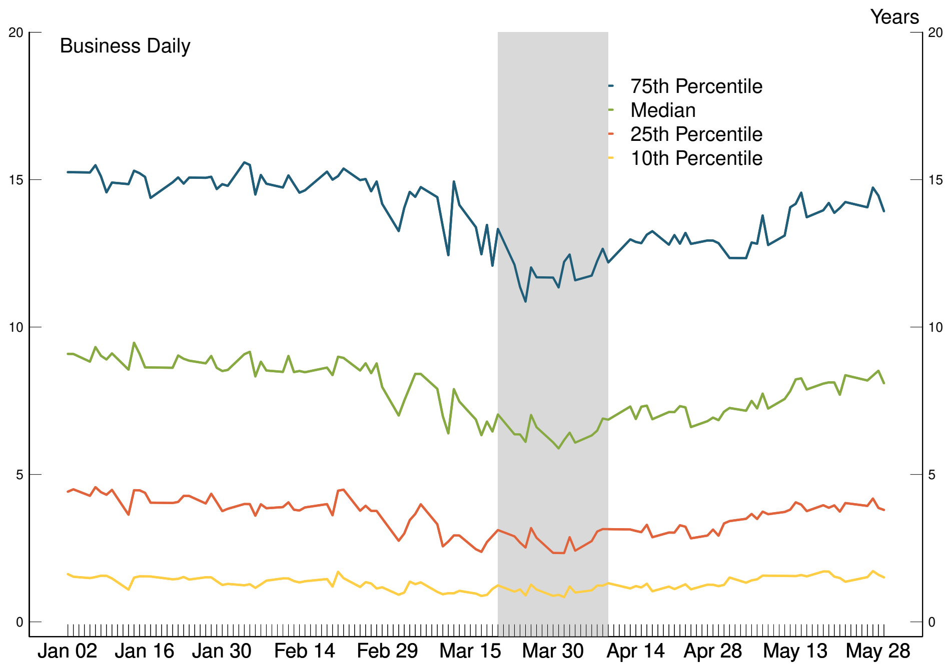
8. For the state of Louisiana, we replace the search for "cnty" with "parish".

D Additional Data Statistics

In line with the acute stress affecting shorter maturity bonds, the average remaining maturity of traded bonds declined at the peak of the crisis. Figure D1 shows that prior to the pandemic, the trading distribution across maturities was fairly stable, with the top quartile of daily trades having a remaining maturity of 15 years throughout January and February. In late March, however, the top quartile saw a notable decline, reaching about 12 years at its trough. The median maturity level of trades followed a similar pattern, but to a lesser degree. Notably, the remaining maturity for the bottom 10th percentile of trades was largely unchanged throughout the period at around 1 year, even though these bonds experiencing sharp increases in their yields. The comparison highlights that trading activities shifted from the very long maturity bonds, those above 15 years, to the range of 10 to 15 years, while trading was not dominated by the securities experiencing the highest increases in yields.

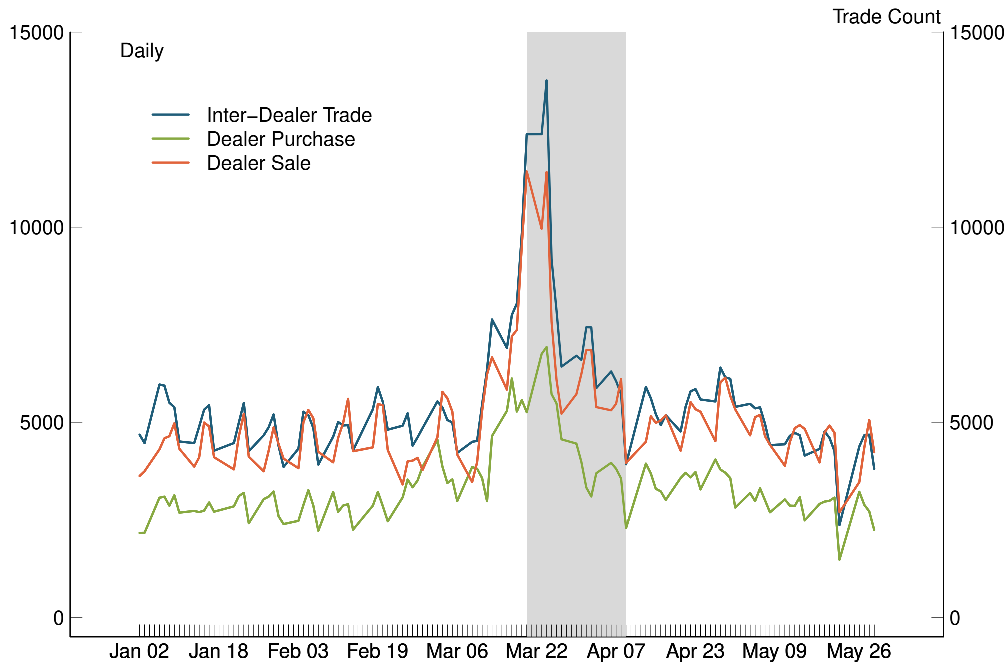
Figure D2 compares three types of municipal market trading activities: inter-dealer transactions, bond sales from dealers to customers, and dealer bond purchases from customers. While all three types of trading activities increased in mid- and late-March, dealer bond sales and inter-dealer transactions rose more rapidly than dealer bond purchases from customers. Accordingly, dealer inventories of municipal bonds fell during the first quarter, according to the Federal Reserve's Z.1 Flow of Funds release.

Figure D1: Remaining Maturity Distribution



Source: Municipal Securities Rulemaking Board.

Figure D2: Trade Count: Purchase vs. Sale vs. Inter-dealer transaction



Source: Municipal Securities Rulemaking Board.

E Event Study Summary Stats

Table E3: Event Study Summary Stats

	Full Sample		MMLF		MMLF Revised		Agreement		CARES Senate		CARES House		MLF	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
	No Intervention	3/19-4/9	excluded	included	excluded	included	excluded	included	excluded	included	excluded	included	excluded	included
Yield	179.937	270.991	321.701	330.308	346.127	352.377	342.197	349.396	260.307	251.135	222.238	216.075	204.412	221.499
	(81.042)	(93.421)	(81.452)	(76.579)	(75.272)	(72.478)	(69.326)	(70.714)	(76.087)	(81.153)	(75.590)	(79.399)	(76.883)	(96.258)
Maturity (years)	9.460	8.102	8.094	9.724	7.878	10.379	7.721	8.543	7.703	8.056	7.821	9.093	7.964	10.128
	(7.225)	(6.757)	(6.610)	(8.028)	(6.528)	(8.165)	(6.347)	(6.973)	(6.257)	(6.654)	(6.327)	(7.232)	(6.442)	(7.910)
Maturity < 1 year	0.076	0.092	0.088	0.081	0.092	0.067	0.091	0.087	0.098	0.092	0.090	0.074	0.085	0.056
	(0.266)	(0.290)	(0.283)	(0.273)	(0.289)	(0.250)	(0.288)	(0.282)	(0.298)	(0.289)	(0.286)	(0.262)	(0.279)	(0.229)
Investment Grade	0.966	0.966	0.966	0.975	0.964	0.984	0.964	0.976	0.960	0.973	0.964	0.975	0.967	0.979
	(0.181)	(0.181)	(0.181)	(0.157)	(0.187)	(0.127)	(0.187)	(0.152)	(0.196)	(0.163)	(0.187)	(0.157)	(0.179)	(0.142)
Speculative Grade	0.031	0.032	0.033	0.025	0.036	0.016	0.036	0.024	0.038	0.026	0.035	0.022	0.031	0.020
	(0.174)	(0.177)	(0.178)	(0.157)	(0.186)	(0.127)	(0.186)	(0.152)	(0.192)	(0.158)	(0.184)	(0.146)	(0.173)	(0.140)
Not Rated	0.003	0.001	0.001	0.000	0.001	0.000	0.001	0.000	0.002	0.002	0.001	0.003	0.002	0.001
	(0.052)	(0.035)	(0.032)	(0.000)	(0.025)	(0.000)	(0.026)	(0.015)	(0.041)	(0.041)	(0.036)	(0.059)	(0.047)	(0.026)
Principal Amount	27.179	27.626	13.910	54.537	13.713	57.573	12.775	51.169	12.346	60.550	13.853	69.866	14.967	119.602
	(210.429)	(186.039)	(94.436)	(133.514)	(50.341)	(170.524)	(55.511)	(187.289)	(43.773)	(347.445)	(50.223)	(388.924)	(50.431)	(711.700)
Observations	1,078,044	301,177	35,984	15,451	39,531	15,971	40,346	18,277	29,391	10,800	24,639	9,502	18,852	5,875

Notes: Columns show mean values for bond characteristics with standard deviations in parentheses. First two columns compare bonds traded between March 23 and April 9, the dates of the monetary and fiscal interventions, and all other dates in the full sample. Columns (2) - (14) show bonds included in each event study compared to bonds trade on event study dates but excluded from our sample because they were trade on prior to or after the event but not both before and after the event within the event window.

F Money Market Mutual Fund Effects

The Federal Reserve established the MMLF to directly assist MMMFs and to stabilize the broad financial conditions. During the height of the crisis, investors quickly pulled cash from money market funds, and MMMFs needed to sell their asset holdings to generate cash in order to meet redemption requests. As security prices declined, raising cash through asset and security sales became more difficult. By establishing the MMLF, the Federal Reserve provides a backstop to money market funds by facilitating purchases of assets via commercial banks. Specifically, the Federal Reserve accepts certain high-quality assets – including certain municipal bonds that are purchased from prime and tax-exempt money market funds – as collateral from commercial banks, BHCs, and U.S. branches of foreign banks, and issues short-term loans to those banks. In this way, the Federal Reserve can provide liquidity to MMMFs and their investors.

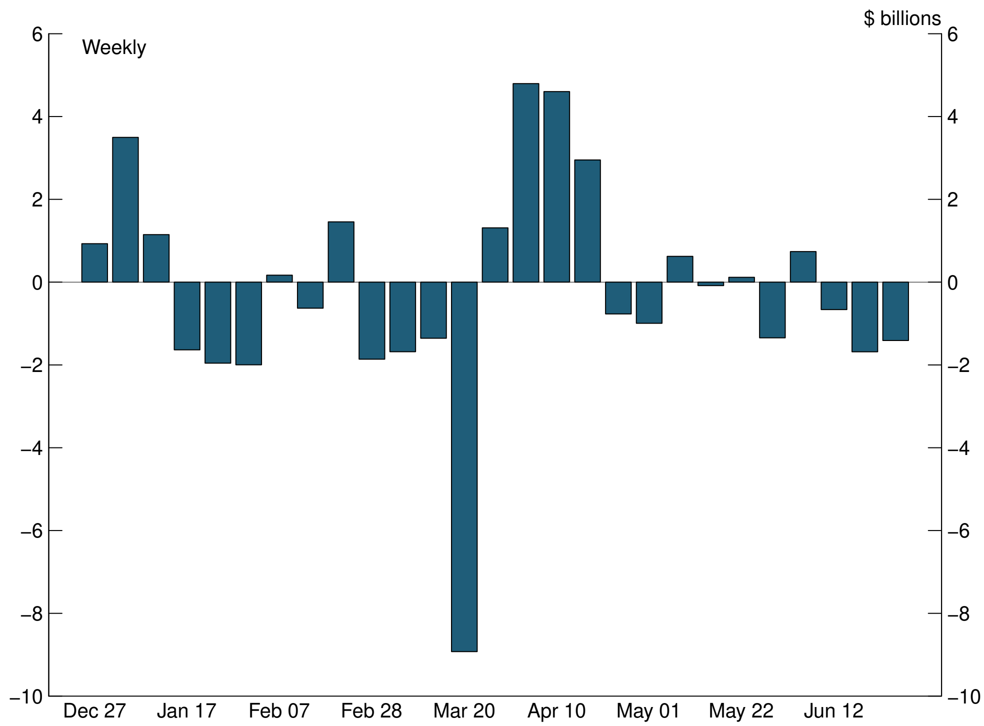
Tax-exempt money market fund redemptions also slowed as shown in Figure F3. Net redemptions had reached a near record level during the week ended March 20, the day of the first intervention by the Federal Reserve into the tax-exempt money fund market. Additional interventions during the following week reversed these outflows and led to a rise in net subscriptions and, since early May, flows have appeared to return to a normal level.

We follow the approach in Duygan-Bump et al. [2013] and study how the MMLF affected the net fund inflows in MMMFs. The structure of the MMLF was much like the Asset-Backed Commercial Paper Money Market Mutual Fund Liquidity Facility (AMLF) during the Great Financial Crisis. Duygan-Bump et al. [2013] explore the effects of the AMLF program on money fund assets and find that it was effective in reducing redemptions. Similarly, we estimate how the establishment of MMLF affected fund flows into MMMFs in general, and in particular those funds with larger shares of assets eligible as MMLF collateral.

We use data from the SEC's Form N-MFP, a required filing for all MMMFs, to estimate the effects of the Federal Reserve programs on flows into money market mutual funds. The report collects monthly data on money market fund assets and security holdings, and also collects subscriptions and redemptions into individual funds at weekly frequency. Unfortunately, there is no daily information reported on N-MFP, and therefore we cannot directly measure the impact of each individual intervention from the Federal Reserve.[14]

[14] Interventions occurred on March 18 (ABCP), March 20 (single state and tax-exempt funds holdings short-term municipal debt), and March 23 (variable rate demand notes).

Figure F3: Net Subscriptions of Tax Exempt Money Market Funds



Source: Form N-MFP, Securities and Exchange Commission.

Accordingly, we estimate the following equation,

$$y_{i,t} = \beta_0 + \beta_1 MMLF_t + \beta_2 MMLF_t \times s_i^{eligible} + \gamma X_i + \varepsilon_{i,t}. \tag{6}$$

$y_{i,t}$ is net fund subscriptions at fund i in week t scaled by end-of-month net assets. We define the dummy indicator $MMLF_t$ which equals 1 for weeks after the week of March 23 to 27, 2020, as the Federal Reserve decided to accept variable rate demand notes on March 23, which was the last Fed announcement associated with the MMLF. The variable $s_i^{eligible}$ denotes the share of eligible asset-backed commercial paper and municipal bond debt held by the money fund at the end of February, before the COVID shock hit the financial system. The vector X_i is a set of fund characteristics measured as of the end of February. We include the fraction of assets maturing in 7 days and the share of liquid assets held, both of which are measures of fund liquidity.[15] We also include an indicator for institutional funds. As a robustness check, we estimate an equation using the average annualized 7-day yield of the fund, following Duygan-Bump et al. [2013]. Standard errors are clustered at the fund level.

Table F4: Money Market Liquidity Facility Effects

	(1)	(2)	(3)	(4)	(5)
Post MMLF Indicator × Eligible Asset Share	0.060***	0.060***	0.060***	0.060***	0.063***
	(0.014)	(0.014)	(0.014)	(0.014)	(0.015)
Post MMLF Indicator	-0.721				-0.778
	(0.469)				(0.497)
Eligible Asset Share	-0.052***	-0.052***		-0.006	-0.094***
	(0.011)	(0.011)		(0.016)	(0.016)
Fraction of Assets Maturing in 7 days				0.057***	
				(0.010)	
Liquid Asset Share				-0.003	
				(0.010)	
Institutional fund indicator				-2.122***	
				(0.647)	
Average Annualized Gross 7 Day Yield					-4.844***
					(1.190)
Constant	1.228***	0.211	-0.745*	-2.370***	11.778***
	(0.393)	(0.474)	(0.386)	(0.873)	(2.503)
Week Fixed Effects	N	Y	Y	Y	N
Fund Fixed Effects	N	N	Y	N	N
Observations	3,552	3,552	3,552	3,552	3,362
Adjusted R^2	0.012	0.021	0.020	0.037	0.020

Notes: Dependent variable is weekly net subscriptions divided by end of month net assets. Post MMLF date is March 27, 2020. Standard errors clustered by fund series.
t statistic in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

We find that the MMLF program had a significant and large effect on reversing outflows for funds that held large shares of eligible assets, even though the impact wasn't significant in general across all money market mutual funds. As shown in table F4, the indicator for the post-MMLF dummy is insignificant for all specifications. On the other hand, our estimates on the interaction term between the MMLF indicator and the eligible asset share are positive and significant, indicating that funds with large shares of eligible asset saw net subscriptions following the program announcement. Those estimates are robust across different specifications that vary with fund control variables, time and fund fixed effects,

[15] We follow Duygan-Bump et al. [2013] and define liquid assets as the stock of Treasuries, Agency debt, and repos.

and the inclusion of average annualized 7-day yield.

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