Pre-trade Information in the Municipal Bond Market

Louis Craig, Abby Kim, and Seung Won Woo[1]

July 2018

Abstract

This white paper documents wide variations in ATS dealer quotes across municipal bonds and examines the characteristics of bonds that dealers tend to quote more often. Dealer quotes represent the primary source of pre-trade information in the municipal bond market. Conditional on a bond being traded, the majority of bonds have pre-trade information. When quotes are posted, two-sided quotes are rare and offer quotes are more common than bids. While a large number of dealers quote some bonds each day, quoting activity in any individual bond on a given day is concentrated among a few dealers. We document variations in quote-based transaction cost measures and price improvement across bonds, and examine the characteristics of bonds that have higher costs. The majority of customer trades execute at worse prices than best available dealer quotes, which might indicate a lack of knowledge of existing quotes. These facts highlight the relative dearth of accessible pre-trade information in municipal bond markets.

[1] The U.S. Securities and Exchange Commission, as a matter of policy, disclaims responsibility for any private publication or statement of any of its employees. The views expressed herein are those of the authors and do not necessarily reflect the views of the Commission or of the authors' colleagues upon the staff of the Commission.

1. Introduction

The majority of municipal bonds trade on dealer-dominated decentralized over-the-counter markets. The main investors in municipal bonds are retail investors who have less information about the market than dealers and institutional investors.[2] Retail investors must rely on dealer quotes to glean information from the market prior to trading. Academic studies have indicated that the lack of transparency and the resulting information asymmetry between dealers and customers is one of the main drivers for high transaction costs for retail investors and lower market quality in this market.[3] In this regard, retail traders benefit the most from pre-trade transparency in the municipal bond market.

Since the introduction of the Municipal Securities Rulemaking Board's (MSRB)'s Real-Time Report System (RTRS) in 2005,[4] post-trade information on municipal bond trading has been available publicly. The RTRS reports the price and size of each trade. The public dissemination of post-trade information has provided some transparency and has enhanced liquidity and price efficiency in the municipal bond markets.[5] However, because municipal bonds trade infrequently, the last-trade information is often stale by the time of the next trade, providing less useful information to customers.

Both policymakers and academics have called for further exploration of the potential efficacy of mandating pre-trade transparency, which refers to displaying orders and prices via bid and offer quotes.[6] For example, former Commission Chair White requested the Commission staff to focus

[2] One study by the Federal Reserve Board indicates that the percent of municipal bonds owned by retail investors has been decreasing over time. However, retail investors still hold the majority of municipal bonds regardless of the decline in their ownerships. See http://www.msrb.org/msrb1/pdfs/MSRB-Brief-Trends-Bond-Ownership.pdf for details.

[3] See Harris and Piwowar (2006)

[4] The MSRB's end of day post-trade reporting commenced in 1994 for inter-dealer trades and in 1998 for dealer to customer trades. The MSRB's RTRS commenced on January 31, 2005. Since then, the MSRB has required nearly all municipal trades to be reported to the MSRB within 15 minutes of trading and transaction information has been disseminated online almost immediately (see MSRB Notice 2005-02 for details, http://www.msrb.org/Rules-and-Interpretations/Regulatory-Notices/2005/2005-02.aspx?n=1). The real-time transaction data became available on a public website (InvestingInBonds.com) through a partnership between MSRB and the Bond Market Association (now part of SIFMA). In March 2008, the MSRB launched EMMA (Electronic Municipal Market Access) as a pilot system. Since then, the MSRB has provided transaction information publicly on a real-time basis on the EMMA website (see https://emma.msrb.org/.)

[5] Chalmers, Liu, and Wang (2017) document that post-trade transparency benefited both large and small trades in terms of a significant reduction in overall trading costs and intra-day price dispersion. Schultz (2012) suggests that the effects of post-trade transparency are limited, but he studies newly-issued bonds which are inherently more liquid. For corporate bond markets, Bessembinder, Maxwell, and Venkataraman (2006), Edwards, Harris, and Piwowar (2007), Goldstein, Hotchkiss, and Sirri (2007), and Bessembinder and Maxwell (2008) show that increased post-trade transparency improved market quality.

[6] In 2012, the Commission released a special study on the municipal bond market. The report concluded that enhancing price transparency and promoting fair access to those prices could improve market efficiency, promote competition, and ultimately facilitate the best execution of retail customer orders in municipal securities. In addition,

on enhancing pre-trade transparency in corporate and municipal bond markets, particularly with respect to retail-size orders.[7] The academic community has also expressed concerns on the lack of pre-trade transparency and has suggested developing facilities to display pre-trade information.[8] Because of limited data availability, little is known about the availability of pre-trade information in the municipal bond market and little research analyzes municipal bond quoting activities.[9]

Pre-trade information could provide important pricing information for municipal bonds, particularly because post-trade information is not up-to-date or unavailable for these infrequently traded securities. Greater pre-trade transparency could potentially reduce information asymmetry between dealers and customers and also lower customers' search costs, leading to lower transaction costs in the municipal bond markets. Furthermore, lower transaction costs could enhance overall market liquidity and contribute to a lower cost of capital for municipalities that use bond markets to obtain funding.

On the other hand, increased competition resulting from additional transparency could deter entry for certain dealers. Furthermore, with mandatory pre-trade transparency, thinly traded bonds may become more illiquid if dealers are reluctant to provide pre-trade price information for those bonds. Additionally, if some uncompetitive dealers exit as a result of more transparency and competition, there could be a reduction in liquidity in the bonds for which those dealers have market power. After all, understanding the current state of pre-trade information in the market is essential to assess the effects of enhancing pre-trade transparency in the municipal bond market.

This white paper is the first to document wide variations in the availability of pre-trade information existing in the municipal bond market[10] Using dealer quote data obtained from ATSs, we provide descriptive statistics of dealer quotes for municipal bonds on ATSs, the types

---

in 2013, the Commission held a roundtable on corporate and municipal bond markets that contained lengthy discussions on mandating pre-trade transparency in those markets.

[7] "Intermediation in the modern securities markets: putting technology and competition to work for investors", Chair Mary Jo White, https://www.sec.gov/news/speech/2014-spch062014mjw.

[8] Harris, Kyle, and Sirri (2015) propose the Commission mandate to develop and use facilities that display and execute customer orders.

[9] Harris and Piwowar (2006), Green, Hollifield, and Schurhoff (2007), Schultz (2012), and Siri (2014) study dealer-intermediation and trading costs in the municipal bond markets using transaction-level data from MSRB. Recently, Harris (2015) studied corporate bond markets using quote data from Interactive Brokers. Moreover, Bloomfield and O'Hara (1999), Flood, Huisman, Koedijk, and Mahieu (1999), and Madhavan, Porter, and Weaver (2005) study the effect of pre-transparency on market quality. Because of data limitation, these studies use experimental settings or equity markets data. There is no academic study that uses quote data to analyze the effect of pre-transparency in the municipal bond markets.

[10] Generally, an ATS is defined as any organization, association, person, group of persons, or system that meets the definition of "exchange" within the meaning of Section 3(a)(1) of the Exchange Act and Rule 3b-16 thereunder, but does not: (a) set rules governing the conduct of subscribers other than the conduct of such subscribers trading on the ATS; or (b) discipline subscribers other than by exclusion from trading. An ATS that complies with Regulation ATS, which includes, among other things, registering as a broker-dealer and filing a Form ATS with the Commission, is not required to register as a national securities exchange under Section 5 of the Exchange Act.

of municipal bonds for which dealers provide quotes, and the characteristics of dealers who provide quotes on ATSs. Furthermore, we use ATS dealer quotes to estimate municipal bond transaction costs.

The descriptive statistics and accompanying analyses on pre-trade information serve as a resource to Commission staff, academic researchers, policy commentators, and investors who are interested in the municipal bond market. Furthermore, the descriptions on current state of pre-trade transparency in the municipal bond market can help to inform future policy decisions regarding information dissemination in this market.

<u>Summary of main findings</u>

We summarize our main findings as follows:

- Among the bonds traded, the majority of bonds have pre-trade information in the form of dealer quotes.
- Conditional on a bond having dealer quotes, more than 90% of bonds have one-sided quotes on an average day, typically on the offer side.
  - The majority of dealer bid quotes are in response to requests for bids wanted, while most dealer offer quotes are unprompted quotes.
- Few municipal bonds have dealer quotes on consecutive days.
- Bonds with dealer quotes have an average issue size more than 1.5 times larger than bonds without dealer quotes.
- Dealers who trade a larger number of bond issues and a higher par volume are more likely to provide quotes on ATSs.
- Transaction costs vary across different types of bonds, but are consistently larger for customer trades than for interdealer trades.
- When two-sided quotes exist, the majority of customer trades are executed outside of the best quoted prices even though trade size does not exceed quote size.
  - In contrast, the majority of interdealer trades are executed very close to the best quoted prices.
- When one-sided quotes exist, the majority of customer trades execute at a price worse than the best available dealer quotes – we find positive average dealer markups in customer trades.
  - Positive average markups on customer trades are driven by positive markups on customer-buy trades.
  - Smaller customer trades (i.e. less than $100,000) have larger markups than larger customer trades.
- Dealer quoting activity suggests a lack of quote competition.
  - On average, less than five dealers quote a given bond per day.

2. Background on dealer quotes on municipal bond ATSs

The use of electronic venues in municipal bond trading has become more prevalent in recent years, and ATSs represent one type of electronic venue that host municipal bond trading.[11] Much of the pre-trade information generated in the municipal bond market is in the form of price quotes available on municipal bond ATSs – electronic trading platforms where dealers post quotes, request quotes, and execute trades.[12] When quote information is posted on an ATS, it is generally available to ATS participants as well as certain retail and institutional investors who subscribe to quote consolidators or obtain such information from broker dealers. Thus, unlike in the equity market where the public can observe intra-day quote prices,[13] pre-trade price information in municipal bond markets is only available to a limited group of market participants. As a result, while dealers may use available quote information to negotiate prices with customers, most retail customers generally do not have direct access to quote information when negotiating prices with dealers.

The main providers of quotes on ATSs are dealers, though these dealers vary in how they interact with the market. Some dealers provide quotes and trade the same bonds. Other dealers use ATSs to trade or to obtain current price quotes but do not post quotes of their own. When no bids are available on an ATS, dealers can also post requests for bids wanted on ATSs.[14] In the following sections, we describe the characteristics of dealers who provide quotes to ATSs and present statistics regarding the number of and characteristics of securities for which dealers provide quotes during the sample period.[15]

We focus our study on two types of dealer quotes on ATSs: posted quotes and responses to request for bids wanted (RBWs). Posted quotes are often referred to as "live or continuous quotes" by ATSs. Posted quotes are generally anonymous and contain information on current quote price and size that are available and accessible by ATS subscribers. When a request for bids wanted is initiated on an ATS, dealers can submit responses as part of an auction process by quoting prices that match the size of the request.[16] We classify these responses as RBWs. Although very rare, ATSs also might display requests for offers wanted and the resulting responses are offer quotes. We also label responses to requests for offers wanted as RBWs

[11] There are also quote consolidators (or aggregators) in the fixed income electronic markets. Quote consolidators receive quotes from other ATSs or dealers, and provide quotes to their clients, including both institutional and retail investors.

[12] Quotes can be either firm or indicative. However, we cannot differentiate clearly whether quotes are firm or indicative quote in our data.

[13] In equity markets, quotes are free with a fifteen-minute lag, and are available in real time for a fee.

[14] A similar auction procedure is referred as a request for quotes (RFQs) in the corporate bond market. Hendershott and Madhavan (2015) study electronic trading via RFQs using Market Access data and document that periodic electronic auctions are important source of liquidity in corporate bond markets.

[15] Although the main providers of quotes on ATSs are dealers, dealer quote may represent customer orders. To minimize the potential misspecification, we dropped quotes that are clearly not dealer quotes.

[16] The majority of the RBWs are not visible to participants who did not initiate the original request.

throughout the paper. After a bids wanted auction is completed, the customer or dealer that initiated the request can transact at one of the submitted quote prices. Note that RBWs are limited in duration by the auction process and therefore differ from posted quotes.

3. Description of data

The sample period spans from August 22, 2014 to November 28, 2014 (67 business days).[17] We obtained dealer quote data from four ATSs that support municipal bond trading.[18] Our quote data include the following information about each quote: bond issue identifier (CUSIP), date of quote, time stamp, price, quoted size, an indicator for whether a quote is a bid or an offer, a dealer identifier (Market Participant Identifier, or MPID), and an indicator for RBWs. The quote data also include identifiers for cancellations and modifications, which we use to construct clean data that consist of valid quotes.[19]

We also collect trade data from the MSRB's RTRS. For each trade, we obtain trade date and time, par volume, indicators for buy- and sell-trades, and indicators for interdealer or customer trades. We also use dealer identifiers (i.e. MPIDs) for each trade that allow us to combine executed trades with our dealer quote data.

Additionally, we use the Mergent Municipal Bond Securities Database (MBSD) to obtain bond characteristics. From the MBSD, we obtain information regarding initial offering size, maturity date, offering date, bond type (i.e. General Obligation (GO) or revenue bonds),[20] and complexity features of a bond.[21] In addition, we use Thomson Reuters DataScope (DataScope) to obtain credit ratings for individual bonds provided by S&P, Moody's and Fitch.

---

[17] There are four federal holidays during our sample period: Labor Day, Columbus Day, Veteran's Day, and Thanksgiving Day. We exclude these days and weekends from our analysis.

[18] Among the ATSs that we sent the data request, four ATSs provided us with municipal bond quote data. These four municipal ATSs have the majority of market share thus the data we obtained have comprehensive information in this market.

[19] We apply several filters to identify valid quotes. A valid quote has a positive price, a positive quoted size, a valid quote date, a valid time stamp, and a valid MPID. If a quote is cancelled at the same time when a quote is posted, we treat it as invalid and do not include in in our analysis.

[20] Revenue bonds are issued to finance specific projects of various institutions in a municipality and the bonds' cash flows are typically backed by the revenues generated from the projects. Also refer to http://www.msrb.org/Glossary/Definition/REVENUE-BOND.aspx. General obligation bonds are issued to finance the ongoing needs of the municipality and these bonds' cash flows are typically backed by the credit and taxing authority of the municipal government. For additional information, see information from the MSRB, http://www.msrb.org/glossary/definition/general-obligation-bond-or-go-bond.aspx.

[21] Most of municipal bonds have special features such as a call provision, a sinking fund, a special redemption, or a nonstandard interest rate frequency. We count the number of these features for each bond and use them as the number of complexity features.

4. Descriptive statistics for dealer quotes on ATSs

This section provides descriptive statistics for dealer quotes on ATSs.[22] We identify dealers who provide quotes on ATSs using MPIDs. To count the number of dealer quotes on municipal bond ATSs, we identify unique combinations of CUSIP-MPID across all ATSs on each day.[23]

Table 1 presents the number of dealer quotes and the number of bonds quoted on municipal bond ATSs. Table 1 shows that there are approximately 6.2 million dealer quotes during our sample period, and among them there are over 4.2 million dealer offers for 165,737 distinct bonds and over 1.9 million dealer bids for 137,991 distinct bond issues. That is, the total number of offer quotes is more than 50% larger than the total number of bid quotes in our sample. In addition, almost all dealer offers are posted quotes, whereas the majority of dealer bids are RBWs. Approximately 89% of the total dealer bids on ATSs are RBWs on 127,790 distinct bond issues.

Table 2 presents the distribution of the number of dealer quotes per day and the number of days quoted per bond issue conditional on a bond having at least one quote on a given day. The top section of Table 2 shows that there are a median of 92,926 dealer quotes and an average of 92,008 dealer quotes per day in our sample. On a daily basis, the number of offer quotes is more than 50% larger than the number of bid quotes, and approximately 90% of dealer bid quotes per day are RBWs.

The bottom section of Table 2 presents the number of days with at least one available dealer quote at the issue level. During our sample period, there are 67 business days when at least one quote exists. For a given bond, conditional on the bond having quotes, quotes on municipal bond ATSs are available on an average of 16 days (about 24% of the total business days), with a median of 7 days (about 10% of the total business days), indicating that quotes are sparsely available. In addition, conditional on a quote being available for a bond, there are substantially more days when offers are available than when bids are. Offers are available for an average of 18 and a median of 9 days, whereas bids are available for an average of 4 and a median of 2 days. We observe two-sided quotes even less frequently: for a given bond, conditional on the bond having quotes, two-sided quotes are available for an average of 3 days and a median of 1 day.

Table 3 presents the availability of pre-trade (e.g. the availability of price quotes) and post-trade information (e.g. the availability of trade price and size) for total customer trades in our sample. Panel A of Table 3 reports the number of trades reported in the MSRB's RTRS between 8:00 a.m.

---

[22] The MSRB's RTRS does not carry a master list of securities, thus it is not feasible to determine accurately how many municipal securities are outstanding per day. Because of this limitation, the analyses in this paper are conditional on a bond issue having a trade or a quote.

[23] In general, once a dealer's quote is posted on a given day, it stays in the ATS until the end of the day unless the dealer quote updates its price, size or message. Therefore, we count the number of quotes that are unique for a bond for an MPID for each day across all ATSs as the number of quotes per day.

and 6:30 p.m.[24] During the sample period, there are 2,271,590 trades for 222,375 distinct bond issues, and among those trades, 1,417,254 trades are dealer-to-customer trades,[25] representing approximately 62% of the total number of trades.

The second part of panel A of Table 3 reports the availability of pre-trade information at the time of customer trades that were reported to RTRS. For a quote to be defined as available at the time of a customer trade, we require it to stand for at least thirty minutes prior to the time of a trade execution. This is meant to ensure that market participants could have had the time to observe the quote.[26] More specifically, we define available quote price information as a dealer offer quote that precedes a customer-buy trade by thirty minutes, or a dealer bid quote that precedes a customer-sell trade by thirty minutes. Panel A of Table 3 shows that quote price information is available for approximately 54% of customer trades at the time of trade execution in our sample period. As noted above, however, this does not imply that all market participants had access to pre-trade information prior to these trades, since direct or indirect availability of quote price information is restricted to ATS participants and certain institutional and retail investors.[27]

We recognize that prior trade prices can also serve as a useful source of information for both customers and dealers when negotiating trade prices. If a customer trade takes place subsequent to a trade in the same or similar security, the customer may be able to use the information from the earlier trade to determine the price at which she is willing to transact. Therefore we also examine the availability of trade prices prior to a customer trade. Because bonds do not trade every day and trade prices may become stale over time, we restrict attention to post trade information from the same day for a customer trade.

For each customer trade, we identify if there is any previous trade for the same bond at least thirty minutes prior to the trade on a given day. This procedure produces four groups of customer trades: trades with both quote and prior trade price information, trades with prior trade price information but without quote price information, trades without prior trade price but with quote price information, and trades with neither quote nor prior trade price information.

[24] Rule G-14 requires dealers to submit trade reports within 15 minutes of execution from 7:30 a.m. to 6:30 p.m. In Table 2, we report the number of trades between 8:00 a.m. and 6:30 p.m. because we apply thirty minutes interval between a trade and quotes when we analyze the availability of quote price information. When time filters for normal business hours are applied, there are 2,278,033 trades on 222,428 unique CUSIPs in our sample period, and when we do not apply any time filters, there are 2,281,911 trades on 222,450 unique CUSIPs. For more details, see http://www.msrb.org/Rules-and-Interpretations/MSRB-Rules/Facilities/RTRS-Facility.aspx.

[25] For brevity, we refer to dealer-to-customer trades as customer trades henceforth.

[26] To ensure the robustness of our results, we use 15 second, 15 minutes, 30 minutes, and 60 minutes lags between trades and quotes to assess the availability of pre-trade information. When we use different time lags, quote price information exists for approximately between 51 and 57% of customer trades in our sample.

[27] When we exclude RBWs from the analysis, that quote price information is available for approximately 44% of customer trades prior to trades in our sample.

The lower section of Panel A of Table 3 shows that on an average day approximately 35% of total customer trades have available quote price information without price information on prior trades.[28] This subsample may permit us to more clearly assess the impact of available quote price information because for these trades, quote price information is available without the confounding impact of information from recent trades. Additionally, approximately 19% of customer trades have both quote and prior trade price information at the time of a trade. Furthermore, on an average day, for approximately 37% of customer trades neither quote nor prior trade price information is available at the time of the trade, and for approximately 10% of customer trades have prior trade price information but no prior quote price information.[29]

Panel B of Table 3 reports the availability of pre-trade information and prior trade information for customer trades broken out by trade side. We use similar methodology to define the availability of quote price information and prior trade price information as we use in Panel A of Table 3. We identify whether the customer trade is a buy or a sell trade using indicators provided in RTRS.

For customer-buy trades, Panel B of Table 3 shows that on an average day approximately 39% of customer-buy trades have available quote price information without prior trade price information. In addition, approximately 25% of customer-buy trades have both quote and prior trade price information at the time of a trade. Furthermore, on an average day, for approximately 26% of customer-buy trades neither quote nor prior trade price information is available at the time of the trade, and for approximately 10% of customer-buy trades have prior trade price information but no prior quote.[30]

Considering customer-sell trades, Panel B of Table 3 shows that on an average day approximately 27% of customer-sell trades have available quote price information without prior trade price information. In addition, approximately 8% of customer-sell trades have both quote and prior trade price information at the time of a trade. Furthermore, on an average day, for approximately 57% of customer-sell trades neither quote nor prior trade price information is

---

[28] For robustness, we also use 15 minutes, 30 minutes, and 60 minutes between a trade and its prior trade on that day. When we use different time lags between trades, between 31% and 35% of customer trades have quote price information without prior trade price information, between 19% and 23% of customer trades have both quote and prior trade price information at the time of a trade. Between 33% and 37% of customer trades neither quote nor prior trade price information is available at the time of the trade, and between 10% and 14% of customer trades have prior trade price information but no prior quote price information on a given day.

[29] As reported in Table 1, the majority of bid quotes are RBWs, so excluding RBWs from the analysis leads to less price information prior to a customer-sell trade. If we exclude RBWs from the analysis, approximately 26% of customer trades have available quote price information without prior trade price information. In addition, approximately 18% of customer trades have both quote and prior trade price information at the time of a trade. For approximately 45% of customer trades neither quote nor prior trade price information is available at the time of the trade, and for approximately 11% of customer trades have prior trade price information but no prior quote price information.

[30] When we exclude RBWs from the analysis, the results are almost identical to Panel B of Table 2 since the majority of RBWs are bid quotes and not offers,

available at the time of the trade, and for approximately 9% of customer-sell trades have prior trade but no prior quote.[31] As presented in Table 1, there are a substantially larger number of dealer offer quotes than dealer bid quotes in our sample, therefore, it is natural that the availability of quote price information is much less for customer-sell trades than for customer-buy trades.

Table 4 shows the number of bond issues with dealer quotes in our sample period. Panel A of Table 4 presents the distribution of the number of bond issues with dealer quotes per day. The number of issues with bid quotes is about 8,643 per day on average, with a median of 8,499. For the offer side, the average number of bond issues with dealer quotes is 44,607, with a median of 43,934. In addition, the number of issues that have two-sided quotes is about 3,730 on average, with 3,734 at the median. The number of bond issues with quotes shows that very few bonds have two-sided quotes, and conditional on being quoted, a bond is most likely to have an offer quote. Consistent with previous results, the majority of bid quotes are RBWs, and most offer quotes are posted quotes.

Panel B of Table 4 presents the distribution of the number of traded and non-traded bond issues per day by quote availability. The top part of Panel B shows the number of traded bonds reported to RTRS and the ratio of number of bonds with bid, offer, and two-sided quotes, respectively, to the number of traded bonds on a given day. The median number of traded bond issues per day is approximately 12,961, and an average of 12,572 bonds issues are traded per day. In addition, on an average day, approximately 27% of traded bond issues have dealer bid quotes, 66% have dealer offer quotes, and 19% have two-sided dealer quotes on average and at the median.

The bottom part of Table 4 Panel B presents the distribution of the number of bonds being quoted that are not traded for each day, and the ratio of number of bonds with bid, offer, and two-sided quotes, respectively, to the number of bonds that are quoted but are not traded on a given day. On average, approximately 40,000 bond issues in our sample do not trade but have either bid or offer quotes. Additionally, among non-traded bond issues that have dealer quotes, approximately 13% of those bond issues have bid quotes, 91% have offer quotes, and 3% have two-sided quotes on a given day. Furthermore, we observe that there are substantially more bond issues that are quoted but not traded than there are bond issues that are traded but not quoted each day.

[31] When we exclude RBWs from the analysis, on an average day approximately 3% of customer-sell trades have available quote price information without prior trade price information and approximately 3% of customer-sell trades have both quote and prior trade price information at the time of a trade. Approximately 80% of customer-sell trades include neither quote nor prior trade price information and approximately 13% of customer-sell trades have a prior trade but no prior quote.

Table 5 reports the daily distributions of quoted size, as well as the time interval during which quotes are available for each bond issue, conditional on a bond issue being quoted in a given day on any ATS. To calculate these time intervals, we consider quotes available if they are observed during RTRS business hours, from 7:30 a.m. to 6:30 p.m.[32] For each bond with an available quote in a given day, we calculate the hours per day during which there is at least one valid quote. In calculating the number of hours that a bond is quoted when two-sided quotes are available, we identify all time intervals for which there are valid bid and offer quotes provided by at least one dealer and sum them up per bond on a given day.

The first part of Table 5 shows that, conditional on a bond issue being quoted in a given day, the offer quotes are quoted for more than ten hours for at least 75% of bond issues per day. That is, for these bonds, offer quotes are quoted for almost all business hours on a given day. In addition, conditional on a bond issue being quoted in a given day, bid quotes are quoted for at least six hours for approximately 50% of bond issues per day. As previously discussed, bid quotes from RBWs becomes unavailable once a bid wanted request is matched to a response with matching quote size. Therefore, we also compute the number of hours that bid quotes are quoted after excluding RBWs.[33] Excluding RBWs and conditional on a bond issue being quoted in a given day, posted bid quotes are quoted for at least nine hours for approximately 50% of bond issues per day. Furthermore, excluding RBWs and conditional on a bond issue being quoted in a given day, two-sided quotes are quoted for at least seven hours for approximately 50% of bond issues per day.

The second part of Table 5 describes the distribution of quoted size, expressed in $1,000 par volume.[34] When we analyze the size distribution, we include all valid quotes and produce distribution of quoted size for the entire sample period. Table 5 shows that the median bid size is larger than the median offer size.[35] For posted quotes on ATSs, the median bid size is $50,000 whereas the median offer size is $30,000 in par volume. In addition, for bid quotes, the size of posted quotes is larger than that of RBWs.[36] Moreover, in comparison to the corporate bond market during the identical sample period, the quoted size on municipal bond ATSs is smaller than that on corporate bond ATSs.[37]

[32] The time dealers are required by Rule G-14 to submit trade reports within 15 minutes of execution begins at 7:30 a.m. and ends at 6:30 p.m. (http://www.msrb.org/Rules-and-Interpretations/MSRB-Rules/Facilities/RTRS-Facility.aspx).
[33] Offer quotes also include RBWs. However because there are very few offers that are RBWs, we do not include the hours that these quotes are available in our analysis.
[34] We use maximum quote size as a measure of quoted size.
[35] The Wilcoxon rank test of medians shows that the differences in median bid and offer size are statistically significant at the 1% level.
[36] Because there are very few RBW offer quotes, it is difficult to provide meaningful comparisons of quoted size.
[37] Separate analysis of corporate bond ATS data shows that the median bid size is $250,000 and the median offer size is $130,000 in par volume. Moreover, as a comparison, the median trade size of municipal bonds reported to RTRS is $30,000 in our sample.

Overall, the analyses in this section show that bond issues differ in the degree of available pre-trade price information. Quotes are generally one-sided and dominated by offer quotes, and the majority of dealer bids are RBWs whereas most dealer offers are posted quotes. Few municipal bonds have dealer quotes on ATSs over consecutive days. In addition, conditional on a bond issue being quoted in a given day, offer quotes are posted during all business hours for the majority of bonds. Moreover, the number of hours that that bid quotes are quoted for a bond is substantially shorter than the number of hours that offer quotes are quoted for a bond. Finally, the analyses in this section suggest that there are wide variations in dealers' quoting activities across bond issues.

5. Dealer quotes by bond characteristics

In this section, we assess which bond characteristics are associated with the availability of dealer quotes on ATSs, examining offering amount, credit rating, maturity of a bond, time since issuance (age), complexity features, and bond types.[38] To analyze credit ratings, we divide bonds into investment-graded (IG) bonds (i.e. bonds rated BBB– or higher), and high-yields (HY) bonds (i.e. bonds rated lower than BBB–);[39] to analyze bond types, we compare GO bonds, revenue bonds, and the rest;[40] to analyze complexity features, we divide bonds into bonds with two or more complexity features and bonds with zero or one complexity feature.[41]

For all bonds that have at least one trade during the sample period, we study how the distribution of bond characteristics of bond issues with at least one dealer quote differs from those without quotes across the days in our sample. Furthermore, we examine cross-sectional variation of bonds that have only one-sided quotes versus those with two-sided quotes. For each bond characteristic, we perform statistical tests to check whether the differences between bonds with quotes and those without are statistically significant.

Panel A and B of Table 6 presents the cross-sectional distribution of bond characteristics at the day-issue level. Panel A of Table 6 displays the distribution of issue size, maturity, and time since issuance of bond issues with at least one dealer quote and bond issues without quotes on an

[38] Harris and Piwowar (2006) use bond characteristics similar to those we use.

[39] Where available, we use credit ratings from Moody's. When ratings from Moody's are not available we supplement with ratings from Standard & Poor's and Fitch, in this order.

[40] Revenue bonds are issued to finance specific projects of various institutions in a municipality and the bonds' cash flows are typically backed by the revenues generated from the projects. Also refer to http://www.msrb.org/Glossary/Definition/REVENUE-BOND.aspx. General obligation bonds are issued to finance the ongoing needs of the municipality and these bonds' cash flows are typically backed by the credit and taxing authority of the municipal government.

[41] Complexity features include callable, sinking fund, early or special redemption, or nonstandard interest rate frequency (see Harris and Piwowar (2006)). For robustness, we include varying interest rates as an additional complexity feature and find our results and inferences do not change.

average day.[42] Panel B of Table 6 presents the percentage of bond issues quoted based on credit quality, the number of complexity features, and bond type for each bond issue on an average day. For example, to examine credit quality we calculate the percentages of bonds quoted for investment-grade and high-yield bonds; for complexity features of bonds we calculate the percentages of bonds quoted for bonds with two or more complexity features and bonds with less than two complexity features; and for bond types we calculate the percentages of bonds quoted for GO bonds, revenue bonds, and other bonds, respectively, and present them at the day-issue level.

The distribution statistics in Panel A of Table 6 suggest that bonds with quotes tend to have larger issue sizes than bonds without quotes. The average and the median issue size ($34.8 million and $7.0 million, respectively) for bond issues quoted on ATSs is substantially larger than the average and the median issue size ($21.6 million and $4.6 million, respectively) for bond issues that are not quoted on ATSs on a given day. Unlike the distribution of issue size, we note little difference in original maturity and time since issuance between bonds that are quoted and those that are not quoted on ATSs.[43]

Panel B of Table 6 reports the percentage of bonds quoted for bonds by credit ratings category, number of complexity features, and bond type. Most municipal bonds in our sample have investment-grade credit ratings regardless of quote availability. In addition, bonds that are quoted have more complexity features than bonds that are not quoted. Furthermore, we find little difference in bond types between bonds that are quoted and those that are not quoted on ATSs.

Panel A and Panel B of Table 6 also present the comparison of characteristics of bond issues that have only one-sided quotes versus those with two-sided quotes. Table 6 shows that bonds with two-sided quotes have larger issue size than bonds without two-sided quotes. We also find weak evidence that bonds with two-sided quotes have longer original maturity and longer time since issuance than bonds with one-sided quotes. For credit quality, bond type, or the number of complexity features, there are no meaningful differences in the incidence of one-sided or two-sided quotes.[44] In addition, consistent with previous findings, there are more bonds with one-sided quotes than with two-sided quotes regardless of bond characteristics.

---

[42] When bonds are one-sided, we find similar results in the association between bond characteristics and dealer quote availability.

[43] There is weak evidence that newer issues with longer maturity are more likely to have ATS quotes. We test whether the differences in characteristics between ATS-quoted and other bonds are statistically significant. *t*-test and Wilcoxon rank sum tests report means and medians are significantly different at the 1% level for each characteristic. However, these differences are not economically significant (except for issue size).

[44] Formal statistical tests suggest that bonds with two-sided quotes have larger issue size and longer maturities, and are relatively older than bonds with one-sided quotes. We also note that the difference in issue size has the most meaningful economic significance in terms of its magnitude.

Overall, the analyses in this section indicate that bonds with larger issue sizes are associated with a higher incidence of quotes; however, we find little difference in quoting activity across other bond characteristics in our sample. We also observe minor differences in the incidence of one-sided relative to the incidence of two-sided quotes for bonds with different characteristics.

6. Transaction costs measures

In this section, we examine quoted spreads, effective spreads, price improvement to quoted spreads, and markups to quote (markups) constructed from the best bids and offers (BBOs) using all valid quotes on municipal bond ATSs in our sample.[45] Our study is the first to compute transaction costs using both dealer quotes and trade prices.[46] Because of data availability, most academic studies rely on trade-level data to estimate transaction costs for municipal bonds, and focus on the markups of customer trades relative to interdealer trades. In contrast to these studies, we compute quote-based transaction costs for all trades when two-sided quotes are available. Furthermore, we compute the markups for customer trades for a given bond when there is at least one standing quote at the time of trade execution on a given day. Pre-trade information is almost nonexistent for investors. Therefore our analysis of transactions costs based on quotes may provide useful information to investors and regulators.

Table 7 reports the distribution of time-weighted quoted spreads for municipal bonds at the issue-day level for periods during which two-sided quotes are available.[47] Using BBOs calculated during RTRS business hours, from 7:30 a.m. to 6:30 p.m., we compute quoted spread as the best offer price less the best bid price normalized by the midpoint of the best bid and offer prices.[48] During the sample period, the median time-weighted quoted spread is approximately 159 basis points (bps) and the average is approximately 262 bps.[49] For the cheapest-to-trade quartile of bonds, the time-weighted quoted spread is about 75 bps, and for the costliest-to-trade quartile of bonds, it is approximately 317 bps, which is substantially larger than quoted spread in

---

[45] In our sample, the majority of dealers quote on multiple ATSs and the majority of bond issues are quoted on multiple ATSs so we compute BBOs using quotes across all ATSs using both posted quotes and RBWs. In the Appendix we report statistics for these and subsequent variables after excluding RBWs and our results are largely unchanged.

[46] Harris and Piwowar (2006) estimate effective spreads using transaction-level data and show that municipal bond trades are significantly more expensive than equivalent-sized equity trades.

[47] At the security level, a median of 5.8% of bonds experience a crossed market, and 2.6% experience a locked market at least once over the sample period. To reduce data errors, we remove the CUSIPs when locked or crossed markets exist more than 25% of the day (as a percentage of time that two-sided quotes are available). We explore varying ratios (10%, 30%, and 50%) for robustness and find no changes. Furthermore, to remove outliers in the data, we winsorize the quoted spreads at the 1% and 99% level.

[48] Quoted spread is defined as (best offer price – best bid price)/(midpoint of the best bid and offer prices).

[49] Using trade-level data and regression-based estimation methods, Harris and Piwowar (2006) document that the average transaction costs range from 24.4 bps to 134.3 bps for trades with trade size between $5,000 and $1,000,000.

the corporate bond market.[50] We note that very few bonds have two-sided quotes and the analysis in this section is based on information that represents approximately 33% of our overall sample of bond issues with some quote information.[51]

Table 7 also reports the distribution of time-weighted quoted spread across six bond characteristics for the sample period.[52] Except for the largest quartile of bonds, time-weighted quoted spreads increase monotonically with issue size. Median time-weighted quoted spreads are approximately 128 bps for bonds with issues size less than $1 million, 138 bps for bonds with issue size between $1 million and $10 million, and 176 bps for bonds with issue size greater than $10 million. Also, quoted spreads are larger for bond issues with lower credit quality, longer original maturity, and more complexity features. Additionally, revenue bonds tend to have larger quoted spreads than GO bonds.[53] Furthermore, quoted spreads are smaller for new bond issues (fewer than 6 months since issuance) than for seasoned bond issues, although among seasoned bond issues, we do not observe clear patterns in quoted spreads.[54]

Using the BBOs, we also calculate the effective spread as a second measure of transaction costs for trades when two-sided quotes are available between 7:30 a.m. and 6:30 p.m.[55] We examine only trades for which two-sided quotes are available for at least one second[56] prior to the trade to

[50] Harris (2015) reports that the average quoted spread in the corporate bond market is less than 135 bps. Using data from different time periods, DERA's analyses document that the time-weighted median quoted spread for corporate bonds is approximately 74 bps (173 bps as an average).

[51] The number of bond issues that we calculate quoted spread is 68,040, representing approximately 33% of total bond issues with either bid or offer quotes in our sample.

[52] The association between quoted spreads and each bond characteristic is almost identical regardless we exclude RBWs, except for two cases. Time-weighted quoted spreads increase monotonically with issue size for all deciles. In addition, quoted spreads also increase monotonically with time since issuance for all deciles.

[53] The differences in mean and median quoted spreads for each bond characteristic are statistically different at the 1% significance level.

[54] Overall, the distribution of bond characteristics is consistent with Harris and Piwowar (2006). We note that we can calculate quoted spread only for approximately 33% of total bond issues with either dealer bids or offers in our sample, and therefore, the association between quoted spreads and bond characteristics requires caution. The distribution of bond characteristics presented in Table 7 is conditional on bonds having two-sided quotes and do not represent the association between quoted spreads and bond characteristics in the entire market.

[55] In computing effective spreads and price improvement measures (and markups below), we filter out unreasonable prices in order to remove outliers and errors in the trade prices. More specifically, we compute five-day moving median of traded prices, and require that a trade price is within 10% range of median prices. We only use principal trades in computing transaction costs. We further winsorize effective spreads at the 1% and 99% level. After applying these filters, there are 331,644 total principal trades (44,834 unique bonds) for which we calculate effective spreads and price improvement. We try alternative methods to mitigate the influence of data errors and outliers, such as excluding the observation when the difference between best bid and offer prices are greater than $100 and find the distributions of effective spreads and price improvement remain almost identical.

[56] In Table 3, we are interested in the availability of any quote price that stands for at least thirty minutes prior to a trade. In this section, we focus on measuring transaction costs using the best bid and offer prices at the time of trade execution. Therefore, we use one second to identify the best quote prices available at the time of trade execution.

permit market participants with access to quote information to adjust to that information before engaging in trade.[57] The results are reported in Table 8.

For customer trades, we can identify whether the trade is a buy or a sell trade using an indicator provided in RTRS.[58] We estimate the full effective spread for customer-buy trades as twice the difference between the trade price and the midpoint of the best bid and offer prices, normalized by the midpoint of the best bid and offer prices. For customer-sell trades, we estimate the full effective spread by multiplying the midpoint less the trade price by two before normalizing by the midpoint.[59] If the trade price is identical to the midpoint of the best bid and offer prices, the effective spread for the trade is zero.

Unlike customer trades, it is unclear to identify the direction of interdealer trades from RTRS. We identify an interdealer trade as buyer-initiated if the trade price is greater than the midpoint of the bid and ask price and as seller-initiated if the trade price is less than midpoint of the bid and the ask price.[60] We estimate the full effective spread for buyer-initiated interdealer trades as twice the difference between the trade price and the midpoint of the bid and offer prices, normalized by the midpoint of the bid and offer prices. For seller-initiated interdealer trades, we estimate the full effective spread by multiplying the midpoint less the trade price by two before normalizing by the midpoint.

Panel A of Table 8 shows that the median full effective spread is approximately 172 bps, and the average full effective spread is approximately 231 bps. As previously noted, quotes in the municipal bond market are largely one-sided and these quotes do not permit estimation of effective spreads. This means that our estimates of effective spreads are based on approximately 15% of the trades in our sample (331,644 out of 2,278,033 all trades between 7:30 a.m. and 6:30 p.m.). Focusing on the distinction between interdealer trades and customer trades, effective spreads are substantially larger for customer trades. The average effective spread for customer trades is almost 1.8 times as large as that of interdealer trades (287.6 bps versus 161.2 bps), and the median effective spread for customer trades is almost three times as large as for interdealer

[57] Harris (2015) uses two-second quote standing time prior to trades when estimating effective spread in corporate bond markets. To check the robustness of our results, we estimate the effective spread using the two-second quote standing time. The results are almost identical to Table 8 and our inference does not change.

[58] Bessembinder and Venkataraman (2010) discuss the definition and implementation issues for various transaction cost measures. They note that equity market transaction cost studies use quoted midpoints to identify the direction of trades. Our data identifies buy and sell trades. As a comparison, when we use midpoints to identify the direction of customer trades, the median effective spread is 182.4 bps, and the average effective spread is 273.0 bps. Although our overall inference does not change in either case, the effective spreads for customer trade computed by using the information from RTRS give us a precise way to estimate the effective spread that customers pay for trades relative to dealers.

[59] Formally, for buy trades the effective spread is 2 × (trade price – midpoint)/quote midpoint, and for a customer-sell trade the effective spread is 2 × (midpoint – trade price)/quote midpoint.

[60] Harris (2015) uses the same method to identify the direction of trades from TRACE in corporate bond markets.

trades (269.3 bps versus 91.1 bps). This result is consistent with findings from academic studies documenting that customers pay more than dealers when trading fixed income securities.[61]

We also examine whether effective spreads differ by trade size for customer trades and interdealer trades, respectively. In Panel A of Table 8, we show that transaction costs are generally smaller for larger customer and interdealer trades.[62] For customer trades, the median effective spread is 292.3 bps for trades of less than $25,000, 277.7 bps for trades of between $25,000 and $100,000, 184.1 bps for trades of between $100,000 and $1,000,000, and 35.6 bps for trades of greater than $1,000,000.[63] For interdealer trades, the median effective spread is 125.8 bps for trades of less than $25,000, 86.9 bps for trades of between $25,000 and $100,000, 51.5 bps for trades of between $100,000 and $1,000,000. The median effective spread is 56.3 bps for trades of greater than $1,000,000, slightly larger than for trades of between $100,000 and $1,000,000.

Panel A of Table 8 also shows that except for very large trades (greater than $1,000,000) effective spreads are substantially larger for customer trades than for interdealer trades of all sizes. We also observe instances where dealers incur losses in customer trades.[64] For example, for customer trades of greater than $1,000,000, the effective spread for the cheapest-to-trade quartile of bonds is approximately –85 bps; for customer trades of between $100,000 and $1,000,000, the effective spread for the cheapest-to-trade decile of bonds is about –41 bps. In our sample, these occur for 9% of total customer trades.

The results from Panel A of Table 8 are also consistent with academic studies documenting that municipal bond transaction costs decrease with trade size and that institutional-size customer trades (trades of greater than $100,000) have smaller transaction costs than retail-size customer trades (trades of less than $100,000).[65]

Panel B of Table 8 also reports the distribution of effective spreads across six bond characteristics in our sample.[66] First, the average and median effective spread increases monotonically with issue size. Specifically, the median effective spread is 125.3 bps for bond issues with issue size less than $10 million, 186.5 bps for issue size between $10 million and $50 million, and 193.6 bps for issue sizes greater than $50 million. In terms of credit quality, the

[61] DERA's analysis and Harris (2015) document that corporate bond market effective spreads are larger for customer trades than interdealer trades.
[62] Hong and Warga (2004) and Harris and Piwowar (2006) also document that transaction costs are larger for smaller trades than large trades.
[63] Mean effective spreads can be affected by a few bonds with extremely large values. Therefore, we use median and the overall distribution to assess the association between effective spreads and trade size.
[64] Out of 184,288 customer trades, 16,628 trades have negative effective spreads in our sample.
[65] Harris and Piwowar (2006) use trade size of $100,000 to distinguish retail- and institutional-size customer trades.
[66] Our overall inference on the association between each bond characteristic and effective spreads does not change when we exclude RBWs. One exception is time since issuance, where we do not observe clear patterns in effective spreads across different groups.

majority of bonds have investment grade credit ratings, and bond issues with high-yield credit ratings are associated with larger effective spread than those with investment-grade credit ratings. Moreover, bond issues with longer maturity at issuance have larger effective spreads than bond issues with shorter maturity. We note that the majority of bond issues for which we compute effective spreads have an original maturity that is longer than 10 years.

In terms of time since issuance, bond issues that are less than six months old tend to have smaller median effective spreads than those that are older than six months, though these relatively younger bonds represent less than 10% of the sample of trades with two-sided quotes available. When comparing middle-aged bonds (between 6 months and 5 years old) to old bonds (older than 5 years), there are no clear differences between effective spreads for these two groups. Additionally, revenue bonds and bonds with two or more complexity features have larger effective spreads than GO bonds and bonds with one or no complexity features.

Next, we examine a price improvement measure using RTRS trade data and BBO quotes. First, we compute price improvement for each trade when two-sided quote prices are available at the time of trade execution. To compute this measure we match trades with the best available quote using the same methodology we used to compute effective spreads. We examine only trades for which a quote is available for at least one second prior to the trade to permit market participants observe the quotes before the trade took place.[67]

For customer trades, we also identify whether the trade is a buy or a sell trade using the indicator provided in RTRS while for interdealer trades, we identify a trade as a buy trade if the trade price is greater than the midpoint of the best bid and ask prices and as a sell trade if the trade price is less than midpoint of the best bid and the ask prices.[68] We compute price improvement as the trade price less the bid price normalized by the midpoint of the best bid and offer prices for a sell trade, and as the offer price less the trade price normalized by the midpoint of the best bid and offer prices for a buy trade.[69] Price improvement of zero indicates that a sell trade was executed at the best bid price or a buy trade was executed at the best offer price. A negative value for price improvement indicates that the trade was executed outside of the best bid and offer prices, and a positive value for price improvement indicates the customer trade was executed within the best bid and offer prices.

Panel A of Table 9 reports the distribution of price improvement broken out by interdealer and customer trades and by trade size. Both average and median price improvement for customer

[67] For robustness, we also examine trades for which a quote is available for at least two seconds prior to the trade to permit market participants observe the quotes before the trade took place and find similar results to Table 9.
[68] This is identical to the way we identify the direction of trades when estimating effective spreads. We can compute effective spreads and price improvement to the midpoint when two-sided quotes exist.
[69] Formally, for a sell trade this is (trade price – best bid price)/quote midpoint, and for a buy trade this is (best offer price – trade price)/quote midpoint.

trades are negative, indicating that the majority of customer trades are executed outside of the best bid and offer prices. As a contrast, the average price improvement for interdealer trades is 5.2 bps and the median price improvement is zero, indicating that the majority of interdealer trades are executed very close to the best bid and offer prices. We note again that quotes are mostly one-sided, thus the price improvement measures presented in Panel A of Table 9 stem from only 15% of the trades in our overall sample.

We also assess whether the negative price improvement for customer trades is driven by certain trade sizes. The distribution in Panel A of Table 9 indicates that the majority of customer trades receive negative price improvement. Furthermore, at least 75% of customer trades with trades of less than $100,000, at least half of customer trades of between $100,000 and $1,000,000, and at least 25% of customer trades of greater than $1,000,000 are executed outside of the best quoted spreads (i.e., negative price improvement). Panel A of Table 9 also suggests that institutional-size customer trades (trades of greater than $100,000) tend to receive more positive price improvement than retail-size customer trades (trades of less than $100,000).

We contrast these findings with price improvement for interdealer trades where we observe that the median price improvement of interdealer trades is zero for all trade sizes. This means that at least half of interdealer trades are executed near the best bid and offer prices for all trade sizes. Moreover, where price improvement is negative, the magnitude of the negative price improvement is substantially smaller than that of customer trades for all trade sizes. We note that in most cases the trade size of both customer and interdealer trades does not exceed the quoted size. That is, the fact that the majority of customer trades are executed outside of the best bid and offer prices is not driven by dealer quote sizes being smaller than the size of customer trades.

Lastly, we compute a similar measure, expressed in bps, when only one-sided quotes are available at the time of trade execution, which we refer as markups. We compute markups only for customer trades because we cannot identify the direction of interdealer trades without the midpoint of the bid and offer prices, while a trade indicator in RTRS provides information about the direction of customer trades. We also note that quotes are mostly one-sided, concentrated on the offer side. Therefore, the majority of markups estimates are computed based on trades where only offer prices were available at the time of trade execution.[70]

As above, we examine only trades for which a quote is available for at least one second prior to the trade to permit market participants with access to pre-trade information to observe the most recent quote prices before the trade took place.[71] Then we calculate the markups for a buy trade as the trade price less the offer price normalized by the offer price, and for a sell trade as the bid

[70] As presented in Panel B of Table 9, the number of customer-buy trades is 396,550, approximately 88% of total number of customer trades for which we compute markups.
[71] We also use 2 seconds prior to trades for robustness and our inferences do not change.

price less the trade price normalized by the bid price.[72] Positive markups for a customer trade indicate that the investor pays more than the best quote available at the time of trade execution; zero markups imply the customer's order was executed at the best available quote; and negative markups for a customer trade indicate that the customer received a better price than the best available quote.

As an illustrative example, if the best offer price is 100 and a customer pays 102 for a buy trade, the markup to quote is (102–100)/100=0.02, or 200 bps. For this buy trade, the customer pays an additional 200 bps relative to the best available dealer offer quote. Similarly, if the best bid price is 100 and a customer receives 98.5 for a sell trade, the markup to quote is (100–98.5)/100=0.015, or 150 bps. For this sell trade, the customer receives 150 bps less than the best available dealer bid quote.

Panel B of Table 9 reports the distribution of markups for customer trades broken out by trade side and trade size.[73] The average markups are 69.9 bps and the median is 64.2 bps. We note that the majority of customer trades are customer-buy trades, with a markup of 75.7 bps at the median and 78.5 bps on average. For customer-sell trades, the median markups are 23.2 bps and the average markups are 7.8 bps, indicating the majority of markups for customer trades are driven by the positive markups from the customer-buy trades.

Panel B of Table 9 also presents the distribution of markups broken out by customer-buy and customer-sell trades and across different trade sizes. For customer-buy trades of less than $25,000 and trades of between $25,000 and $100,000, at least 75% of the trades have positive markups; and for customer-buy trades with trades of between $100,000 and $1,000,000, at least half of the trades have positive markups. On the other hand, for customer-buy trades with trade size greater than $1,000,000, at least half of trades have negative markups.

The distribution statistics also indicate that the majority of customer-buy trades execute at a price worse than the best available offer quotes, and the overall average markups are greater for trades with smaller trade size than trades with larger trade size. While for very large customer-buy trades (greater than $1,000,000) customers obtain better trade prices than the best quotes, these large trades represent only about 2% of customer-buy trades with offer quotes available. As indicated by the number of trades for each trade size group, most customer-buy trades are for less than $100,000 (more than 80% of total customer-buy trades), therefore, the results suggest

[72] Formally, it is (trade price – best offer price)/best offer price for a customer-buy trade and (best bid price – trade price)/best bid price for a customer-sell trade.

[73] When we exclude RBWs, the results are very similar to Panel B of Table 9 for customer-buy trades. In terms of customer-sell trades, for trades of all size groups, at least 75% of the trades have negative markups (the majority of customer-sell trades receive higher prices than the best available dealer bid quote). However, after excluding RBWs, the number of customer-sell trades is less than 1% of total customer trades in our sample.

that for the majority of buy trades, customers pay a higher price than the best available dealer offer quote when one-sided quotes exist.

For customer-sell trades, except for trades of between $25,000 and $100,000, at least half of the trades have positive markups; for customer-sell trades of between $25,000 and $100,000, approximately 75% of the trades in our sample of customer-sell trades have positive markups. As indicated by the number of trades for each trade size group, the majority of customer-sell trades also have trade size less than $100,000 (more than 86% of total customer-sell trades), so for the majority of customer-sell trades, customers receive lower prices than the best available dealer bid quotes.[74] The results also indicate that markups are substantially larger for retail-size trades (less than $100,000) than for institutional-size trades (greater than $100,000) for both customer-buy and customer-sell trades.

In sum, we observe that municipal bond transaction costs are higher for customer trades than interdealer trades, and for retail-size customer trades than institutional-size customer trades. We also document cross-sectional variation in transaction costs among securities related to certain bond characteristics and trade size. Moreover, our work is novel in that we document differences in prices paid by dealers and customers using quote information, and compare customer trade prices to quotes. When two-sided quotes exist, the majority of customer trades are executed outside of the best quoted prices, and the majority of interdealer trades are executed very close to the best quoted spread. Computing markups when one-sided quotes exist, we find that the majority of customer trades are executed at a price worse than the best available quote, and that customers receive worse prices for smaller, retail-size trades in our sample.

7. Quoting activities of dealers on the ATSs

This section provides descriptive statistics regarding dealers' quoting activity and discusses dealer concentration in quote provisions on municipal bond ATSs. We analyze the association between dealer size and quote availability, the number of bond issues for which each dealer provides quotes, and the number of quoting dealers per issue. We note that the analyses are based on bond issues that have at least one valid quote each day in our sample.

First, we examine how dealer size is related to quote availability. We obtain all valid trades from RTRS, and combine them with quotes from the ATSs. Our quote and trade data have MPIDs, which enable us to link dealer characteristics and dealer quote activities. We conjecture that large dealers trade more bonds in larger volumes than small dealers. For each dealer we construct two

[74] For customer-sell trades, the signs of average and median are different, indicating the presence of large outliers in the data. Customer-sell trades also exhibit greater variance than customer-buy trades.

measures of dealer size: the total par volume traded and the number of issues traded during the year prior to our sample period. We refer to the one year period prior to the start of our sample period as the 'estimation period.' Conditional on a dealer trading on a bond during the sample period and the estimation period, for each day and each MPID, we identify all bonds that have at least one trade during the sample period and assign an indicator equal to 1 if a dealer provides at least one quote per day. We then divide the dealers into four size groups and assess how the propensity for a dealer providing quotes differs across the four groups.

Table 10 presents how dealer size is related to each dealer's propensity to quote on ATSs on a given day. For both measures of dealer size, we find that large dealers tend to quote more than smaller dealers. For example, if we use the total par volume traded as the measure of dealer size, the average daily propensity for the top quartile of dealers to provide quotes is 78% during our sample period, whereas the average daily propensity for the bottom quartile of dealers to provide quotes is 19%. Furthermore, if we use the number of issues that dealer traded one year prior as the measure of dealer size, the average daily propensity for the top quartile of dealers to provide quotes is 84%, whereas the average daily propensity for the bottom quartile of dealers to provide quotes 22%. Similar patterns appear when we use one-sided quotes to examine dealers' quoting activity.

Table 11 reports the number of bond issues that each dealer quotes per day. We count the number of bond issues at the day-MPID level and produce the distribution of the number of bonds across trading days. Compared to the number of bond issues with dealer quotes from Table 4, dealers quote for only a few bonds per day. On average, a dealer provides either bid or offer quotes for 326 bond issues, bid quotes for 121 issues, and offer quotes for 286 issues on a given day. At the median, a dealer provides either bid or offer quotes for 39 bond issues, bid quotes for 12 issues, and offer quotes for 40 issues on a given day. In addition, consistent with the results in the previous section, within bids, dealers provide quotes for more bonds through RBWs than through posted quotes, and within offers, most of the offers are posted quotes and very few are RBWs. As manifested by the wide range of the number of bond issues in the distribution, there are large variations across dealers in the number of bond issues for which they provide quotes.

Table 12 presents the number of dealers quoting each bond issue when there is at least one dealer quote on a given day. We calculate relevant statistics at the day-issue level and produce the distribution across days for which quotes are available. Two-sided quotes in this table indicate that both bids and offers exist whenever a dealer quote is available on a given day.

When bid quotes are available on our sample ATSs, there are approximately four dealers quoting on average (two dealers at the median) per issue on a given day. For the offer side, there are about three dealers quoting on average (two dealers at the median) per issue. Table 12 also reports that there are approximately four dealers quoting on average (three dealers at the median) for each issue when quotes are two-sided per day.[75] Considering the total number of dealers who provide at least one quote per day and the total number of bond issues quoted in our sample, the results from Table 12 indicate that there is dealer concentration in quoting activity for each bond issue.

To broaden our understanding of dealer concentration in quoting activity, we provide additional analysis of the issues that have two-sided quotes. We first collect bond issues that have two-sided quotes on a given day and count the number of trades in these issues in our sample. We then divide the issues into five groups according to the number of trades, assigning to group 1 for issues that account for the top 20% of trades, to group 2 for those that account for the next 20%, and so on. Table 13 presents the daily distribution of number of dealers providing two-sided quotes for each group of bond issues. The median number of dealers ranges from two to four and the average number of dealers ranges from three to five, indicating that regardless of trade frequency, there is dealer concentration in providing two-sided quotes on the ATSs.[76]

In sum, we document that dealers that trade more issues and larger par volumes tend to provide more quotes per day. We also find that there is dealer concentration in quote provision for each bond issue in our sample. In addition, we observe large variation across dealers in the number of issues for which they provide quotes.

8. Conclusion

Pre-trade price information is available to the majority of municipal bonds traded in the form of dealer quotes, however, only a limited group of market participants have access to the pre-trade information. Those with direct or indirect access to pre-trade price information include dealers and certain institutional and retail investors, who may obtain access to quotes as clients of dealers. Using dealer quote data on municipal bond ATSs, we present general descriptive statistics on the availability of pre-trade information in municipal bond markets. We find that there are varying degrees of pre-trade price information available during the sample period.

We also document a number of patterns in quote availability in the municipal market. Quotes are generally one-sided and dominated by posted offers, and the majority of bid quotes are responses

[75] There are 387 unique dealers who provide either bid or offer quotes in our sample. Among those dealers, 302 dealers provide offer quotes and 365 dealers provide bid quotes.

[76] We note that there is weak evidence that more dealers provide two-sided quotes for more frequently traded issues in our sample (for example, the median number of dealers for top 20% of trades are four, while the median number of dealers for bottom 20% of the trade are two.) However, the difference is economically insignificant.

to requests for bids (RBWs). Quotes are sparsely available across trading days. However, once a dealer offer quote is posted, it remains valid on the ATS most of the day. We find wide variation in dealers' quoting activities across bond issues and evidence that dealers concentrate quoting activity in individual bonds. Furthermore, we show that bonds with quotes have larger issue sizes than bonds without quotes, and dealers that trade more issues and large volumes are more likely to provide quotes on municipal bonds ATSs.

Additionally, we observe cross-sectional variation in transaction costs among municipal bonds based on bond characteristics and trade size. Lastly, we find evidence for higher transaction costs for customer trades than for interdealer trades, and positive average dealer markups in customer trades.

These descriptive statistics and accompanying analyses improve our understanding of pre-trade transparency in the municipal bond markets. Larger issues are more likely to have dealer quotes, but other bond characteristics show little relation with quoting activity. We find that quotes are available for bonds on days without trades, suggesting that some dealer quotes are less stale than the most recent trade prices. Lastly, our analysis of transaction costs indicates retail investors receive worse prices than prevailing quotes so they may benefit if dealer quote information were more widely available.

9. References

Bloomfield, Robert, and Maureen O'Hara, 1999, Market transparency: Who wins and who loses? *Review of Financial Studies*, 12(1), 5–35.

Bessembinder, Hendrik, William Maxwell, and Kumar Venkataraman, 2006, Market transparency, liquidity externalities, and institutional trading costs in corporate bonds, *Journal of Financial Economics*, 82(2), 251–288.

Bessembinder, Hendrik and William Maxwell, 2008, Transparency and corporate bond market, *Journal of Economic Perspectives*, 22(2), 217–234.

Bessembinder, Hendrik and Kumar Venkataraman, 2010, Bid-ask spreads: Measuring trade execution costs in financial markets, in *Encyclopedia of Quantitative Finance*, John Wiley & Sons

Chalmers, John, Steve Liu, and Zhi Jay Wang, 2017, The difference a day make: Timely disclosure and trading efficiency in the muni market, available at SSRN: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2786420.

Edwards, Amy, Lawrence Harris, and Michael Piwowar, 2007, Corporate bond market transaction costs and transparency, *Journal of Finance*, 62(3), 1421–1451.

Flood, Mark D., Ronald Huisman, Kees G. Koedijk, and Ronald J. Mahieu, 1999, Quote disclosure and price discovery in multiple-dealer financial markets, *Review of Financial Studies*, 12 (1), 37–59.

Green, Richard, Burton Hollifield, and Norman Schürhoff, 2007, Financial intermediation and the costs of trading in an opaque market, *Review of Financial Studies*, 20(2), 275–314.

Goldstein Michael, Edith Hotchkiss, and Erik Sirri, 2007, Transparency and liquidity: A controlled experiment on corporate bonds, *Review of Financial Studies*, 20(2), 235–273.

Harris, Lawrence E. and Michael S. Piwowar, 2006, Secondary trading costs in the municipal bond market, *Journal of Finance*, 61(3), 1361–1397.

Harris, Larry, Albert S. Kyle, and Erik Sirri, 2015, Statement of the financial economists roundtable, April 2015: The structure of trading in bond markets, Finance Analysts Journal, 71(6), 5–8.

Harris, Lawrence E., 2015, Transaction costs, trade throughs, and riskless principal trading in corporate bond markets, available at SSRN: https://ssrn.com/abstract=2661801.

Hendershott, Terrence, and Ananth Madhavan, 2015, Click or call? Auction versus search in the over-the-counter market, *Journal of Finance*, 70(1), 419–447.

Hong, Gwangheon, and Arthur Warga, 2004, Municipal marketability, *Journal of Fixed Income*, 14, 86–95.

Madhavan, Ananth, David Porter, and Daniel Weaver, 2005, Should securities markets be transparent? *Journal of Financial Markets*, 8(3), 265–287.

Municipal Securities Rulemaking Board, 2017, Trends in municipal bond ownership, available at http://www.msrb.org/msrb1/pdfs/MSRB-Brief-Trends-Bond-Ownership.pdf.

Schultz, Paul, 2012, The market for new issues of municipal bonds: The roles of transparency and limited access to retail investors, *Journal of Financial Economics*, 106(3), 447–684.

Sirri, Erik R., 2014, Report on secondary market trading in the municipal securities market, Municipal Securities Rulemaking Board, July 2014.

Table 1. Number of dealer quotes and municipal bond issues quoted

Table 1 presents the number of dealer quotes and the number of bonds quoted on municipal bond ATSs We identify dealers who provide quotes on ATSs using MPIDs. To count the number of dealer quotes on muni ATSs, we identify unique combinations of CUSIP-MPID on each day.

	Number of dealer quotes (in million)	Number of bond issues (CUSIPs)
Quote (bid or offer)	6.16	204,377
Bid	1.91	137,991
Posted quote	0.23	29,546
RBW [77]	1.70	127,790
Offer	4.25	165,737
Posted quote	4.24	163,265
RBW	0.01	2,646

Data source: ATSs

[77] RBW stands for responses to requests for bids or offers wanted.

Table 2. Number of dealer quotes per day and number of days quoted per bond issue

Table 2 presents the distribution for the number of dealer quotes per day and the number of days quoted per bond issue (CUSIP) conditional a bond having at least one quote on an average day.

	Daily distribution							
	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Number of quotes								
Bid or offer	92,008	78,207	83,008	87,884	92,926	96,255	101,376	102,614
Bid	28,568	20,803	23,157	26,870	28,838	31,370	33,492	33,875
Posted quote	3,365	2,453	2,644	3,040	3,342	3,681	4,238	4,480
RBW [78]	25,299	18,162	19,729	23,700	25,873	28,082	29,738	30,548
Offer	63,440	55,433	56,497	58,976	63,594	65,668	71,732	72,928
Posted quote	63,255	55,278	56,355	58,752	63,417	65,531	71,557	72,749
RBW	187	124	130	148	180	221	259	282
Number of days quoted per issue (CUSIP)								
Bid or offer	16	1	1	2	7	23	52	67
Bid	4	1	1	1	2	3	9	16
Posted quote	7	1	1	1	1	5	21	45
RBW	3	1	1	1	1	3	6	10
Offer	18	1	1	2	9	27	57	67
Posted quote	18	1	1	3	9	27	57	67
RBW	3	1	1	1	1	3	6	9
Both bid and offer	3	1	1	1	1	3	6	11

Data source: ATSs

[78] RBW stands for responses to requests for bids or offers wanted.

Table 3. The availability of pre-trade and post-trade information

Table 3 reports the availability of pre-trade and post-trade information for customer trades in our sample. Panel A presents the number of trades between 8:00 a.m. and 6:30 p.m., and the availability of price quotes for customer trades that were reported to RTRS. We define quote price information as availability of a dealer offer quote preceding a customer-buy trade by thirty minutes, or a dealer bid quote preceding a customer-sell trade by thirty minutes. To assess the availability of prior trade price information, for each customer trade, we identify if there is any previous trade for the same bond at least thirty minutes prior to the trade. Panel B presents the availability of quote price and trade price information prior to a trade by trade side.

Panel A: Number of trades on RTRS and the availability of pre-trade and post-trade information

	Number of trades	Number of bond issues (CUSIPs)
Total	2,271,590	222,375
Customer trade	1,417,254	221,890
Interdealer trade	854,336	153,870
	Number of customer trades	**% of total customer trades**
Customer trade with quote price information	762,262	53.8%
No prior same-day trade	493,230	34.8%
With prior same-day trade	269,032	19.0%
Customer trade without quote price information	654,992	46.2%
No prior same-day trade	519,088	36.6%
With prior same-day trade	135,904	9.6%

Data source: ATSs, RTRS

Panel B: The availability of pre-trade and post-trade information by trade side

	Number of customer-buy trades	% of total customer-buy trades
Customer buy trade	916,048	
Customer trade with quote price information	589,777	64.4%
No prior same-day trade	358,330	39.1%
With prior same-day trade	231,447	25.3%
Customer trade without quote price information	326,271	35.6%
No prior same-day trade	235,135	25.7%
With prior same-day trade	91,136	10.0%
	Number of customer-sell trades	**% of total customer-sell trades**
Customer sell trade	501,206	
Customer trade with quote price information	172,485	34.4%
No prior same-day trade	134,900	26.9%
With prior same-day trade	37,585	7.5%
Customer trade without quote price information	328,721	65.6%
No prior same-day trade	283,953	56.7%
With prior same-day trade	44,768	8.9%

Data source: ATSs, RTRS

Table 4. Number of bond issues with dealer quotes

Table 4 shows the number of bond issues (CUSIPs) with dealer quotes. Panel A presents the distribution of the number of bond issues with dealer quotes per day. Panel B presents the distribution of the number of traded and non-traded bond issues per day by quote availability.

Panel A: Number of bond issues with dealer quotes per day

	Daily distribution							
	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Bid	8,643	6,728	7,416	8,053	8,499	9,369	10,065	10,939
Posted quote	3,177	2,322	2,423	2,858	3,150	3,491	4,042	4,236
RBW[79]	5,743	4,243	4,647	5,254	5,704	6,174	6,594	7,686
Offer	44,607	40,476	40,948	42,179	43,934	47,102	48,637	49,554
Posted quote	44,507	40,405	40,841	42,072	43,857	46,977	48,544	49,453
RBW	102	68	72	84	102	120	132	143
Two-sided quote	3,730	3,041	3,076	3,474	3,734	4,050	4,269	4,386

Data source: ATSs

[79] RBW stands for responses to requests for bids or offers wanted.

Panel B: Number of traded and non-traded bond issues per day by quote availability

	Daily distribution							
	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Number of traded bonds reported to RTRS (CUSIPs)[80]	12,572	9,601	10,830	11,569	12,961	13,526	14,686	15,166
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Traded bonds with bid quotes	27.7%	24.5%	24.9%	26.1%	27.7%	29.3%	30.4%	31.2%
Traded bonds with offer quotes	65.9%	63.3%	63.5%	64.5%	66.1%	67.4%	68.2%	69.0%
Traded bonds with both bid & offer quotes	19.2%	16.8%	17.3%	18.3%	19.3%	20.3%	20.8%	21.4%
Number of quoted bonds that are not traded (CUSIPs)[81]	40,168	35,694	36,096	37,248	39,915	42,900	43,992	45,078
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Non-traded bonds with bid quotes	12.8%	10.4%	11.2%	11.8%	12.8%	13.7%	14.6%	15.1%
Non-traded bonds with offer quotes	90.5%	88.2%	88.6%	89.6%	90.6%	91.3%	92.2%	92.4%
Non-traded bonds with both bid and offer quotes	3.3%	2.8%	2.9%	3.0%	3.2%	3.4%	4.0%	4.1%

Data source: ATSs, RTRS

[80] The top part of Panel B reports the number of traded bond reported to RTRS and the ratio of number of bonds with bid, offer, and two-sided quotes, respectively, to the number of traded bonds on a given day. The number of traded bonds with both bid and offer quotes include both the bonds with bid quotes and the bonds with offer quotes, therefore, the sum of percentage of traded bonds with bid quotes, traded bonds with offer quotes, and traded bonds with both bid and offer quotes exceeds 100%.

[81] The bottom part of Panel B reports the distribution of the number of bonds being quoted that are not traded for each day, and the ratio of number of bonds with bid, offer, and two-sided quotes, respectively, to the number of bonds that are quoted but are not traded on a given day. The number of non-traded bonds with both bid and offer quotes include the bonds with bid quotes and the bonds with offer quotes, therefore, the sum of percentage of non-traded bonds with bid quotes, non-traded bonds with offer quotes, and non-traded bonds with both bid and offer quotes exceeds 100%.

Table 5. Quote duration and quoted size

Table 5 reports the distribution of daily quote duration hours per a bond issue and quoted size conditional a bond having at least one quote on an average day.

	Distribution							
	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Quoted standing time (in hour)								
Bid	5.53	0.08	0.25	1.28	6.10	8.90	11.00	11.00
Excluding RBW[82]	7.68	0.19	2.14	5.53	8.89	10.50	11.00	11.00
Offer	10.10	6.70	8.58	10.13	10.55	11.00	11.00	11.00
Two-sided	5.60	0.08	0.46	2.41	5.80	8.65	10.97	11.00
Excluding RBW	6.53	0.04	0.24	3.36	7.35	10.00	11.00	11.00
Quoted size (in $1,000 par volume)								
Bid	NM[83]	5	10	20	50	100	250	500
Posted quote	NM	10	10	45	100	150	500	715
RBW	NM	5	5	10	25	50	110	220
Offer	NM	5	10	15	30	115	475	975
Posted quote	NM	5	10	15	30	115	475	975
RBW	NM	5	8	13	30	100	200	350

Data source: ATSs

[82] RBW stands for responses to requests for bids or offers wanted.
[83] NM stands for not meaningful. Because of a few extreme quoted sizes, the mean value of the quoted size is extremely large and does not provide meaningful information regarding the distribution of quoted size.

Table 6. Dealer quotes by bond characteristics

Table 6 presents the cross-sectional distribution of bond characteristics at the day-issue level. Panel A presents the daily distribution of offer size, maturity, and time since issuance of bond issues with at least one dealer quote and bond issues without quotes on an average day. Panel B presents the percentage of bond issues quoted based credit quality, number of complexity features, and bond type for each bond issue on an average day.

Panel A: Distribution of issue size, maturity, and time since issuance

			Distribution							
			Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Issue size (in $million)	Bonds with at least one trade		31.5	0.3	0.6	1.7	6.3	23.1	68.7	125.0
	Not quoted		21.6	0.2	0.4	1.3	4.6	17.8	54.6	97.4
	Quoted		34.8	0.4	0.7	1.9	7.0	25.0	74.3	140.2
	Quoted	One-sided	24.9	0.4	0.6	1.7	5.7	20.0	55.0	100.1
		Two-sided	63.8	0.6	1.0	3.1	13.0	48.0	140.4	263.5
Maturity (in years)	Bonds with at least one trade		16.9	4.7	6.4	10.0	15.8	23.4	29.9	30.5
	Not quoted		16.0	3.2	4.9	8.8	14.9	22.0	29.9	30.8
	Quoted		17.2	5.3	7.0	10.2	16.1	23.9	29.9	30.5
	Quoted	One-sided	16.3	5.0	6.6	9.8	15.0	21.6	29.5	30.2
		Two-sided	19.9	6.8	8.7	12.9	19.7	27.0	30.2	32.0
Time since issuance (in years)	Bonds with at least one trade		5.3	0.1	0.6	2.1	4.7	7.6	9.6	12.1
	Not quoted		6.1	0.3	1.1	2.5	5.7	8.6	10.4	13.7
	Quoted		5.0	0.1	0.4	2.0	4.5	7.4	9.3	11.5
	Quoted	One-sided	4.8	0.1	0.3	1.8	4.2	7.2	9.2	11.1
		Two-sided	5.6	0.4	1.3	2.5	5.1	7.7	9.5	12.5

Data source: ATSs, MBSD, RTRS

Panel B: Percentage of bonds with quotes by credit quality, complexity features, and bond types

			Percentage of bonds with quotes (%)
Credit quality	Bonds with at least one trade		77.1
	Investment grade		74.7
		One-sided	55.7
		Two-sided	19.0
	High yield		2.4
		One-sided	1.1
		Two-sided	1.3
Complexity features	Bonds with at least one trade		74.4
	Two or more complexity features		46.0
		One-sided	32.5
		Two-sided	13.5
	Less than two complexity features		28.4
		One-sided	22.6
		Two-sided	5.8
Bond type	Bonds with at least one trade		74.5
	GO bond		27.4
		One-sided	21.2
		Two-sided	6.2
	Revenue bond		23.6
		One-sided	17.1
		Two-sided	6.5
	Other		23.5
		One-sided	16.9
		Two-sided	6.6

Data source: ATSs, DataScope, MBSD, RTRS

Table 7. Quoted spread and bond characteristics

Table 7 reports the distribution of time-weighted quoted spreads for municipal bonds at the issue-day level for periods during which two-sided quotes are available, and the distribution of time-weighted quoted spread across the following bond characteristics: issue size, credit quality, maturity at issuance, time since issuance, bond types, and the number of complexity features. Using BBOs, we compute quoted spread as (best offer price – best bid price)/(midpoint of the best bid price and the best offer price) during RTRS business hours, from 7:30 a.m. to 6:30 p.m.

		Distribution of time weighted quoted spread (in bps)								
		Number of Observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Overall										
	Time weighted quoted spread	221,253	261.9	20.0	33.2	74.6	159.3	317.2	588.3	852.7
By bond characteristics										
Issue size	Less than $1M	21,217	238.8	14.5	24.4	52.6	127.8	298.9	594.5	820.8
	Between $1M and $10M	74,227	240.2	17.4	28.3	62.1	137.9	284.7	559.7	794.6
	Greater than $10M	118,554	275.4	23.8	38.8	87.1	176.3	335.0	591.0	877.0
Credit quality	Investment grade	191,194	236.9	20.1	32.9	73.2	153.4	297.7	521.0	743.3
	High yield	14,424	602.1	82.0	119.9	215.7	414.1	815.3	1,482.6	1,891.2
Maturity at issuance	Less than 6 months	31	44.8	1.8	3.7	11.1	48.4	56.6	90.0	118.1
	6 months to 5 years	5,265	115.6	9.9	16.7	35.6	70.2	130.3	244.6	311.9
	Greater than 5 years	215,286	264.9	20.6	33.9	76.5	162.6	321.5	593.3	858.1
Time since issuance	Less than 6 months	12,965	163.8	15.1	23.3	45.1	103.3	219.0	382.4	498.0
	Between 6 months and 5 years	93,826	265.2	23.5	37.0	84.9	172.5	325.2	596.1	807.9
	Greater than 5 years	110,340	274.8	19.1	33.0	74.8	160.3	328.1	622.3	969.3
Bond type	Revenue bond	73,253	273.0	21.2	34.9	78.4	165.5	329.9	617.9	916.0
	GO bond	74,609	236.9	17.3	28.9	65.8	146.1	299.6	536.2	760.2
Complexity feature	Two or more complexity features	147,287	273.0	24.0	36.9	83.8	171.8	328.9	610.6	863.9
	Less than two complexity features	73,966	240.0	14.6	25.1	59.9	134.0	293.6	536.7	831.2

Data source: ATSs, DataScope, MBSD

Table 8. Effective spread

Table 8 reports the distribution of full effective spreads for municipal bonds at the issue-day level for periods during which two-sided quotes are available. We estimate the full effective spread as 2 × (trade price – midpoint of best bid and offer prices)/midpoint of best bid and offer prices for customer-buy trades and buyer-initiated interdealer trades; and 2 × (midpoint of best bid and offer prices – trade price)/midpoint of best bid and offer prices for customer-sell trades and seller-initiated interdealer trades. Panel A presents the distribution of effective spread for customer and interdealer trades, and by trade sizes, respectively. Panel B presents effective spread across the following bond characteristics: issue size, credit quality, maturity at issuance, time since issuance, bond types, and the number of complexity features.

Panel A. Full effective spread by trade size

	Distribution of effective spread (in bps)								
	Number of observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Overall									
All trades	331,644	231.4	–0.1	12.5	52.9	172.3	355.1	528.3	678.0
Customer trades	184,288	287.6	–93.0	9.3	113.2	269.3	427.5	581.5	727.3
Interdealer trades	147,356	161.2	6.8	12.9	34.0	91.1	198.6	374.2	557.5
Customer trades by trade size									
Less than $25,000	85,685	305.4	–70.8	23.4	145.0	292.3	436.4	589.2	729.4
$25,000 - $100,000	69,779	299.7	–48.8	20.0	125.7	277.7	436.6	588.6	734.3
$100,000 - $1,000,000	25,012	222.2	–154.3	–40.5	45.3	184.1	357.1	534.5	690.3
Greater than $1,000,000	3,812	94.0	–310.0	–300.1	–84.6	35.6	177.7	426.3	781.9
Interdealer trades by trade size									
Less than $25,000	55,249	196.0	10.6	21.0	53.5	125.8	244.8	434.8	632.4
$25,000 - $100,000	57,425	152.7	7.4	13.4	33.5	86.9	185.1	352.5	526.4
$100,000 - $1,000,000	31,360	118.2	3.7	7.6	20.0	51.5	131.8	281.6	446.3
Greater than $1,000,000	3,322	135.7	3.9	8.3	21.3	56.3	154.8	335.6	533.2

Data source: ATSs, MBSD, RTRS

Panel B. Full effective spread by bond characteristics

		Number of Observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
		Distribution of effective spread (in bps)								
Overall										
	Effective spread	331,644	231.4	–0.1	12.5	52.9	172.3	355.1	528.3	678.0
By bond characteristics										
Issue size	Less than $10M	93,983	197.0	2.8	11.2	36.6	125.3	301.7	471.9	595.5
	Between $10M and $50M	101,949	239.6	0.4	14.2	60.5	186.5	365.7	524.1	675.3
	Greater than $50M	125,548	248.6	–52.8	11.5	66.4	193.6	382.2	566.1	730.0
Credit quality	Investment grade	282,495	218.7	0.5	12.9	51.8	167.5	341.4	496.9	607.6
	High yield	37,440	346.6	–154.1	9.3	93.8	258.1	526.8	870.8	1,235.4
Maturity at issuance	Less than 1 years	35	15.8	–1.1	0.2	2.8	7.9	19.9	39.5	45.8
	1 year to 10 years	30,488	121.4	–32.6	3.7	21.5	74.3	175.1	306.0	411.3
	Greater than 10 years	301,120	242.6	0.0	14.1	59.9	187.6	371.3	542.5	696.4
Time since issuance	Less than 6 months	29,314	211.7	3.3	12.0	36.5	140.2	390.8	488.7	559.2
	Between 6 months and 5 years	126,856	235.9	–11.2	12.5	57.8	178.7	357.0	543.9	700.5
	Greater than 5 years	149,137	230.6	–8.0	12.7	57.0	165.8	328.6	541.6	732.2
Bond type	Revenue bond	120,346	240.9	–8.0	12.8	57.8	183.2	366.1	545.5	703.3
	GO bond	91,224	198.8	0.0	10.3	41.4	137.3	301.3	477.5	605.7
Complexity features	Two or more complex features	266,997	245.9	0.0	14.4	62.2	194.1	378.3	543.4	693.4
	Less than two complex features	64,647	171.8	–11.0	7.0	31.6	104.0	243.2	428.6	597.4

Data source: ATSs, DataScope, MBSD, RTRS

Table 9. Price improvement and markups

Table 9 reports the distribution of price improvement measures for municipal bonds at the issue-day level. Panel A reports the distribution of price improvement to the quote prices when two-sided quote exist, broken out by interdealer and customer trades and across different trade sizes for customer trades and interdealer trades, respectively. When two-sided quotes are available, price improvement is defined as (trade price – best bid)/(midpoint of the best bid and offer prices) for customer-sell trades and seller-initiated interdealer trades, and (best offer – trade price)/(midpoint of the best bid and offer prices) for customer-buy trades and buyer-initiated interdealer trades. Panel B presents markups for customer trades when only one-sided quotes are available at the time of trade execution. The markups are defined as (trade price – best offer price)/best offer price for customer-buy trades and (best bid price – trade price)/best bid price for customer-sell trades.

A. Price improvement for customer and interdealer trades with two-sided quotes

	Distribution of price improvement (in bps)								
	Number of Observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Overall									
All trades	331,644	–28.1	–215.9	–180.5	–88.4	–6.4	5.0	67.3	153.1
Customer trades	184,288	–54.7	–240.9	–206.4	–146.2	–68.6	0.0	93.0	210.7
Interdealer trades	147,356	5.2	–73.5	–38.9	–5.2	0.0	11.1	49.2	99.7
Customer trades by trade size									
Less than $25,000	85,685	–52.8	–239.3	–204.9	–147.8	–70.8	0.0	107.3	224.2
Between $25,000 and $100,000	69,779	–70.7	–245.4	–215.0	–156.9	–76.2	–8.9	49.8	149.2
Between $100,000 and $1,000,000	25,012	–34.8	–229.8	–195.5	–112.4	–39.4	6.5	106.3	224.2
Greater than $1,000,000	3,812	65.9	–176.2	–89.5	–16.2	25.2	128.8	314.9	481.5
Interdealer trades by trade size									
Less than $25,000	55,249	6.6	–88.2	–47.1	–1.4	0.0	12.8	63.4	124.6
Between $25,000 and $100,000	57,425	4.1	–67.7	–38.3	–6.9	0.0	10.8	43.6	89.9
Between $100,000 and $1,000,000	31,360	4.9	–57.9	–26.7	–5.6	0.0	9.4	38.3	76.0
Greater than $1,000,000	3,322	2.5	–79.2	–36.6	–6.6	0.0	15.2	43.0	80.3

Data source: ATSs, RTRS

B. Markups for customer trades with one-sided quotes

	Distribution of markup to quote (in bps)								
	Number of observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Customer trades	451,379	69.9	–77.9	–23.9	0.0	64.2	150.0	201.6	226.4
Buy trades	396,550	78.5	–49.8	–15.3	0.1	75.7	158.6	204.1	229.7
Sell trades	54,829	7.8	–258.5	–134.3	–20.6	23.2	74.4	102.3	143.3
Customer-buy trades									
Less than $25,000	150,921	86.0	–58.6	–9.9	9.4	92.9	168.1	206.2	231.3
$25,000 - $100,000	167,053	88.2	–32.6	–8.6	7.4	90.4	168.3	208.1	233.9
$100,000 - $1,000,000	68,931	51.2	–53.9	–23.3	–1.0	19.7	112.9	186.9	212.8
Greater than $1,000,000	9,645	–13.9	–177.0	–86.9	–31.3	–7.7	7.6	67.4	124.3
Customer-sell trades									
Less than $25,000	28,038	–1.5	–295.7	–171.4	–42.7	19.4	74.4	101.0	144.2
$25,000 - $100,000	19,527	23.6	–166.8	–74.2	0.0	30.9	75.0	109.7	147.2
$100,000 - $1,000,000	6,816	4.3	–240.5	–117.0	–19.0	18.7	61.9	100.0	124.2
Greater than $1,000,000	448	–38.4	–322.8	–322.8	–115.7	0.5	42.1	127.0	294.8

Data source: ATSs, RTRS

Table 10. Dealer size and dealers' quoting propensity

Table 10 presents how dealer size is related to dealers' quoting propensity on ATSs on a given day. Conditional on a dealer trading on a bond during the sample period and the prior one year, for each day and each MPID, we identify all bonds that have at least one trade during the sample period and assign an indicator equal to 1 if a dealer provides at least one quote per day. We then divide the dealers into four groups based on the two empirical measures of dealer size and assess how the propensity that a dealer provides quotes differs across the four groups.

Dealer size	Number of observations	Mean propensity
Total par volume		
Top 25%	6,977	0.78
2nd quartile	6,954	0.78
3rd quartile	6,926	0.53
Bottom 25%	6,940	0.19
Number of bond issues		
Top 25%	6,962	0.84
2nd quartile	6,936	0.72
3rd quartile	6,954	0.50
Bottom 25%	6,945	0.22

Data source: ATSs, RTRS

Table 11. Number of bond issues quoted by a dealer per day

Table 11 reports the daily distribution of number of bond issues that each dealer quotes per day.

	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Bid or offer	326	1	2	7	39	217	690	1765
Bid	121	1	1	3	12	82	308	708
Posted quote	25	1	1	1	3	7	21	147
RBW[84]	123	1	1	3	15	88	314	694
Offer	286	1	2	9	40	169	609	1207
Posted quote	295	1	3	10	44	178	639	1273
RBW	6	1	1	1	2	6	18	28

Data source: ATSs

Table 12. Daily number of dealers providing quotes per bond issue

Table 12 presents the daily distribution of the number of dealers quoting each bond issue when there is at least one dealer quote on an average day.

	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Bid	4.3	1	1	1	2	6	11	14
Offer	3.3	1	1	1	2	3	6	9
Two-sided	4.5	1	1	2	3	6	9	12

Data source: ATSs

[84] RBW stands for responses to requests for bids or offers wanted.

Table 13. Number of dealers providing two-sided quotes by trade frequency

Table 13 presents the daily distribution of number of dealers providing two-sided quotes for each group of bond issues. We divide bond issues into five groups according to the number of trades, assigning to group 1 for issues that account for the top 20% of trades, to group 2 for those that account for the next 20%, and so on.

	Group	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Top 20%	1	5.1	1	1	2	4	7	10	12
	2	4.3	1	1	2	3	6	9	11
	3	4.1	1	1	2	3	6	9	11
	4	3.8	1	1	2	3	5	8	10
Bottom 20%	5	3.5	1	1	1	2	5	8	10

Data source: ATSs, RTRS

Appendix

In this section, we examine quoted spreads, effective spreads, and price improvement measures constructed from the BBOs after excluding RBWs. As previously discussed, the majority of bid quotes are RBWs, thus the analysis after excluding RBWs affects mostly bid quotes and sell-side trades. Naturally, the number of bonds and trades for which we calculate spreads and price improvement is less than when we use both types of quotes in constructing BBOs. As a comparison, we calculate quoted spread for 68,040 unique bonds when we use both types of bid quotes, representing approximately 33% of total bond issues with either bid or offer quotes in our sample. After excluding RBWs, we calculate quoted spread for 23,916 unique bonds, representing approximately 12% of total bond issues with either bid or offer quotes.

Table A1 reports the distribution of time-weighted quoted spreads for municipal bonds at the issue-day level for periods during which two-sided quotes are available. [85] Using BBOs calculated during RTRS business hours, from 7:30 a.m. to 6:30 p.m., we compute quoted spread as the offer price less the bid price normalized by the midpoint of the best bid and offer prices. During the sample period, the median time-weighted quoted spread is approximately 175 bps and the average is 318 bps. For the cheapest-to-trade quartile of bonds, the time-weighted quoted spread is about 59 bps, and for the costliest-to-trade quartile of bonds, it is approximately 400 bps.

Table A1 also reports the distribution of time-weighted quoted spread across six bond characteristics for the sample period. For issue size, time-weighted quoted spreads increase monotonically with issue size for all deciles. Median time-weighted quoted spreads are approximately 81 bps for bonds with issues size less than $1 million, 100 bps for bonds with issue size between $1 million and $10 million, and 220 bps for bonds with issue size greater than $10 million. Also, quoted spreads are larger for bonds with longer time since issuance, lower credit quality, longer original maturity, and more complexity features. Additionally, revenue bonds tend to have larger quoted spreads than GO bonds.[86]

Using the BBOs, we also calculate the effective spread as a second measure of transaction costs for trades when two-sided quotes are available between 7:30 a.m. and 6:30 p.m. We examine only trades for which two-sided quotes are available for at least one second prior to the trade to permit market participants with access to quote information to adjust to that information before engaging in trade.

---

[85] We apply similar filtering and winsorizing methods as we use in Table 7 to filter out unreasonable bid and offer prices when calculating statistics included in the appendix.

[86] The differences in mean and median quoted spreads for each bond characteristic are statistically significant at the 1% level.

We estimate the full effective spread for customer-buy trades and buyer-initiated interdealer trades as twice the difference between the trade price and the midpoint of the best bid and offer prices, normalized by the midpoint of the best bid and offer prices. For customer-sell trades and seller-initiated interdealer trades, we estimate the full effective spread by multiplying the midpoint less the trade price by two before normalizing by the midpoint. For both customer and interdealer trades, if the trade price is identical to the midpoint of the best bid and offer prices, the effective spread is zero.

Panel A of Table A2 shows that the median full effective spread is approximately 144 bps, and the average full effective spread is approximately 226 bps. As previously noted, quotes in the municipal bond market are largely one-sided and these quotes do not permit estimation of effective spreads. This means that our estimates of effective spreads are based on approximately 7% of the trades in our sample after excluding RBWs (166,417 out of 2,278,033 all trades between 7:30 a.m. and 6:30 p.m.). Focusing on the distinction between interdealer trades and customer trades, effective spreads are substantially larger for customer trades. The average effective spread for customer trades is more than 1.8 times as large as that of interdealer trades (291.7 bps versus 154.5 bps), and the median effective spread for customer trades is more than 4.7 times as large as for interdealer trades (293.8 bps versus 62.3 bps).[87]

We also examine whether effective spreads differ by trade size for customer trades and interdealer trades, respectively. In Panel A of Table A2, we show that transaction costs are generally smaller for larger customer and interdealer trades. For customer trades, the median effective spread is 339.1 bps for trades of less than $25,000, 317.3 bps for trades of between $25,000 and $100,000, 178.1 bps for trades of between $100,000 and $1,000,000, and 27.6 bps for trades of greater than $1,000,000. For interdealer trades, the median effective spread is 91.8 bps for trades of less than $25,000, 61.6 bps for trades of between $25,000 and $100,000, 38.1 bps for trades of between $100,000 and $1,000,000. Within interdealer trades, the median effective spread is 53.8 bps for trades of greater than $1,000,000, larger than for trades of between $100,000 and $1,000,000 but smaller than for trades of between $25,000 and $100,000.[88]

Panel A of Table A2 also shows that except for very large trades (greater than $1,000,000) effective spreads are substantially larger for customer trades than for interdealer trades of all sizes. We also observe instances where dealers incur losses in customer trades. For example, for customer trades of greater than $1,000,000, the effective spread for the cheapest-to-trade quartile of bonds is approximately –95 bps; for customer trades of between $100,000 and $1,000,000, the effective spread for the cheapest-to-trade decile of bonds is about –96 bps; for customer trades of

[87] The differences in mean and median effective spreads between customer and interdealer trades are statistically significant at the 1% level.

[88] The mean effective spreads can be affected by a few bonds with extremely large values, thus we use median and the overall distribution to assess the association between effective spreads and trade size.

between $25,000 and $100,000, the effective spread for the cheapest-to-trade decile of bonds is about –13 bps. In our sample, these occur for 13% of total customer trades that we calculate effective spread.[89] The results from Panel A of Table A2 are consistent with academic studies documenting that municipal bond transaction costs decrease with trade size and that institutional-size customer trades have smaller transaction costs than retail-size customer trades.

Panel B of Table A2 reports the distribution of effective spreads across six bond characteristics in our sample. First, the average and median effective spread increases monotonically with issue size. Specifically, the median effective spread is 68.4 bps for bond issues with issue size less than $10 million, 170.2 bps for issue size between $10 million and $50 million, and 181.5 bps for issue sizes greater than $50 million. In terms of credit quality, the majority of bonds have investment grade credit ratings, and bond issues with high-yield credit ratings are associated with larger effective spread than those with investment-grade credit ratings. Moreover, bond issues with longer maturity at issuance have larger effective spreads than bond issues with shorter maturity. We note that the majority of bond issues for which we compute effective spreads have an original maturity that is longer than 10 years. In terms of time since issuance of a bond, we do not observe clear differences in effective spread across different bond groups. Additionally, revenue bonds and bonds with two or more complexity features have larger effective spreads than GO bonds and bonds with one or no complexity features.

Next, we examine a price improvement measure using RTRS trade data and BBO quotes. First, we compute price improvement for each trade when two-sided quote prices are available at the time of trade execution. To compute this measure we match trades with the best available quote using the same methodology we used to compute effective spreads. We examine only trades for which a quote is available for at least one second prior to the trade to permit market participants observe the quotes before the trade took place.

For customer trades, we compute price improvement as the trade price less the bid price normalized by the midpoint of the best bid and offer prices for a sell trade, and as the offer price less the trade price normalized by the midpoint of the best bid and offer prices for a buy trade. Price improvement of zero indicates that a sell trade was executed at the best bid price or a buy trade was executed at the best offer price. A negative value for price improvement indicates that the trade was executed outside of the best bid and offer prices, and a positive value for price improvement indicates the customer trade was executed within the best bid and offer prices.

Panel A of Table A3 reports the distribution of price improvement broken out by interdealer and customer trades and by trade size. Both average and median price improvement for customer trades are negative, indicating that the majority of customer trades are executed outside of the

[89] Out of 86,497 customer trades that we calculate effective spreads, 11,042 trades have negative effective spreads in our sample. This could originate from dealers losing money in certain customer trades or data errors.

best bid and offer prices. As a contrast, the average price improvement for interdealer trades is 6.7 bps and the median price improvement is zero, indicating that the majority of interdealer trades are executed very close to the best bid and offer prices. We note again that quotes are mostly one-sided, and the price improvement measures presented in Panel A of Table A3 represent only 7% of the trades in our overall sample after excluding RBWs.

We also assess whether the negative price improvement for customer trades is driven by certain trade sizes. The average price improvement and median price improvement for customer trades are negative for all trade size groupings except for very large customer trades of greater than $1,000,000. Furthermore, in our sample, at least 75% of customer trades with trades of less than $100,000, at least half of customer trades of between $100,000 and $1,000,000, and at least 25% of customer trades of greater than $1,000,000 are executed outside of the best quoted spreads (i.e., negative price improvement). Panel A of Table A3 also suggests that retail-size customer trades (trades of less than $100,000) tend to receive less price improvement than institutional-size customer trades (trades of greater than $100,000).

We contrast these findings with price improvement for interdealer trades where we observe that the median price improvement of interdealer trades is zero for all trade of less than $1,000,000 and slightly greater than zero for trades of greater than $1,000,000. This means that at least half of interdealer trades are executed near the best bid and offer prices for all trade sizes. Moreover, where price improvement is negative, the magnitude of the negative price improvement is substantially smaller than that of customer trades for all trade sizes.

Lastly, we compute markups when only one-sided quotes are available at the time of trade execution. Similar to Panel B of Table 9, the majority of markups estimates are computed based on trades where only offer prices were available at the time of trade execution. Moreover, after excluding RBWs, the number of customer-sell trades with bid quotes prior to trade execution decreased from 54,829 trades to merely 3,894 trades. In addition, after excluding RBWs, the number of customer-buy trades with only offer quotes increased from 396,550 trades to 461,805 trades.[90]

As above, we examine only trades for which a quote is available for at least one second prior to the trade to permit market participants with access to pre-trade information to observe the most recent quote prices before the trade took place. Then we calculate the markups for a buy trade as the trade price less the best offer price normalized by the best offer price, and for a sell trade as the best bid price less the trade price normalized by the best bid price.

[90] After excluding RBWs, among the trades with one-sided quotes, more than 99% of customer trades are customer-buy trades. Excluding RBWs reduces the number of trades with two-sided quotes.

Panel B of Table A3 reports the distribution of markups for customer trades broken out by trade side and trade size. The average markups are approximately 76.9 bps and the median is 75.8 bps. The majority of customer trades are customer-buy trades, with a markup of 77.4 bps at the median and 78.6 bps on average. For customer-sell trades, the median markups are –85.2 bps and the average markups are –115.9 bps, indicating the majority of markups for customer trades are driven by the positive markups from the customer-buy trades. We note again that because most of customer trades are customer-buy trades, the distribution of markups depend on the markups of customer-buy trades.

For customer buy-trades, the distribution of markups is very close to Panel B of Table 9. For customer-sell trades, at least 50% of the trades have positive markups as reported in the Panel B of Table 9, whereas after excluding RBWs, at least 75% of the trades have negative markups. This indicates that the majority of customer-sell trades with one-sided bid quotes receive price improvement. We also note that customer-sell trades with posted bid quotes are less than 1% of total customer trades that we compute price improvement for. As such, due to the small sample size, the interpretation for the result of customer-sell trades needs caution.

Panel B of Table A3 also presents the distribution of markups broken out by customer-buy and customer-sell trades and across different trade sizes. For customer-buy trades of less than $25,000 and trades of between $25,000 and $100,000, at least 75% of the trades have positive markups; and for customer-buy trades with trades of between $100,000 and $1,000,000, at least half of the trades have positive markups. On the other hand, for customer-buy trades with trade size greater than $1,000,000, at least half of trades have negative markups. These results are similar to Panel B of Table 9.

The distribution statistics also indicate that the majority of customer-buy trades execute at a price worse than the best available offer quotes, and the overall average markups are greater for trades with smaller trade size than trades with larger trade size. While for very large customer-buy trades (greater than $1,000,000) customers obtain better trade prices than the best offer quote, these large trades represent only about 2% of customer-buy trades with offer quotes available. As indicated by the number of trades for each trade size group, most customer-buy trades are for less than $100,000 (more than 81% of total customer-buy trades), therefore, the results suggest that for the majority of buy trades, customers pay a higher price than the best available dealer offer quote when one-sided quotes exist.

For customer-sell trades, for trades of all size groups, at least 75% of the trades have negative markups; so for the majority of customer-sell trades in this analysis, customers receive higher prices than the best available dealer bid quotes. We note again that customer-sell trades with posted bid quotes are less than 1% of total customer trades that we compute price improvement for; therefore it is unclear to draw an inference from the analysis reported in this table.

In sum, we obtain similar results regardless of excluding RBWs from BBOs with an exception for markups for customer-sell trades. Municipal bond transaction costs are higher for customer trades than interdealer trades, and for retail-size customer trades than institutional-size customer trades. When two-sided quotes exist, the majority of customer trades are executed outside of the best quoted prices, and the majority of interdealer trades are executed very close to the best quoted spread. Computing markups when one-sided quotes exist, we find that the majority of customer trades are executed at a price worse than the best available quote, and that customers receive worse prices for smaller trades in in the sample. As discussed above, we find the differences in markups for customer-sell trades. However, because of the minimal number of customer-sell trades, the disparity does not change our overall inference on transaction costs and markups in the municipal bond markets.

Appendix A1. Quoted spread and bond characteristics (excluding RBW)

Table A1 reports the distribution of time-weighted quoted spreads for municipal bonds at the issue-day level for periods during which two-sided quotes are available, and the distribution of time-weighted quoted spread across the following bond characteristics: issue size, credit quality, maturity at issuance, time since issuance, bond types, and the number of complexity features. Using BBOs, we compute quoted spread as (best offer price – best bid price)/(midpoint of best bid and offer prices) during RTRS business hours, from 7:30 a.m. to 6:30 p.m.

		Distribution of time weighted quoted spread (in bps)								
		Number of Observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Overall										
	Time weighted quoted spread	92,234	318.2	13.8	23.6	58.8	174.5	399.5	768.5	1,152.8
By bond characteristics										
Issue size	Less than $1M	8,578	245.1	9.6	15.8	33.2	81.3	305.7	753.6	948.9
	Between $1M and $10M	27,601	275.2	10.4	18.3	39.7	100.4	319.5	757.4	1,125.1
	Greater than $10M	52,962	342.9	17.9	31.6	86.5	219.8	421.1	770.4	1,158.8
Credit quality	Investment grade	73,144	286.5	12.5	21.4	50.7	160.8	373.2	728.6	975.5
	High yield	9,130	599.8	66.9	101.8	199.9	399.6	795.8	1,372.3	1,977.0
Maturity at issuance	Less than 6 months	31	44.4	1.8	3.7	11.1	48.4	56.0	90.0	118.1
	6 months to 5 years	3,026	114.9	8.7	14.1	34.7	73.3	138.0	253.1	309.4
	Greater than 5 years	88,967	323.1	14.1	24.0	60.4	181.6	405.8	773.3	1,160.5
Time since issuance	Less than 6 months	7,044	117.7	10.9	16.3	30.2	62.7	134.1	301.0	433.9
	Between 6 months and 5 years	35,798	309.6	14.5	24.3	61.5	182.2	398.1	762.9	1,036.8
	Greater than 5 years	46,413	366.4	14.6	27.0	77.8	219.9	452.2	875.2	1,336.4
Bond type	Revenue bond	29,383	339.2	14.5	24.6	62.4	191.0	439.0	821.4	1,245.6
	GO bond	33,865	266.3	12.4	21.8	55.4	155.5	337.5	663.2	853.9
Complexity feature	Two or more complexity features	57,273	328.7	15.3	24.7	57.2	179.9	422.1	784.5	1,176.1
	Less than two complexity features	34,961	301.0	11.2	21.3	61.2	166.6	368.3	734.3	1,100.9

Data source: ATSs, DataScope, MBSD

Appendix A2. Effective spread (excluding RBW)

Table A2 reports the distribution of full effective spreads for municipal bonds at the issue-day level for periods during which two-sided quotes are available. We estimate the full effective spread as 2 × (trade price – midpoint of best bid and offer prices)/midpoint of best bid and offer prices for customer-buy trades and buyer-initiated interdealer trades; and 2 × (midpoint – trade price)/midpoint for customer-sell trades and seller-initiated interdealer trades. Panel A presents the distribution of effective spread for customer and interdealer trades, and by trade sizes, respectively. Panel B presents effective spread across the following bond characteristics: issue size, credit quality, maturity at issuance, time since issuance, bond types, and the number of complexity features.

Panel A. Full effective spread by trade size

	Distribution of effective spread (in bps)								
	Number of observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Overall									
All trades	166,417	225.8	–46.8	5.8	31.4	143.6	380.0	558.9	744.3
Customer trades	86,497	291.7	–193.1	–39.0	85.0	293.8	454.3	614.8	807.2
Interdealer trades	79,920	154.5	4.6	9.5	23.3	62.3	176.8	392.8	634.9
Customer trades by trade size									
Less than $25,000	35,683	320.4	–123.1	–0.8	128.3	339.1	465.9	624.1	805.0
$25,000 - $100,000	33,547	311.8	–168.8	–13.1	115.7	317.3	468.3	627.9	822.5
$100,000 - $1,000,000	14,288	217.9	–261.2	–96.2	31.6	178.1	381.6	555.7	761.2
Greater than $1,000,000	2,979	76.0	–532.1	–320.7	–95.2	27.6	175.3	431.6	808.1
Interdealer trades by trade size									
Less than $25,000	25,999	186.2	7.4	13.3	34.5	91.8	223.0	456.8	719.4
$25,000 - $100,000	30,913	153.1	5.1	10.1	23.9	61.6	174.2	389.6	624.1
$100,000 - $1,000,000	20,594	117.5	2.7	5.9	15.0	38.1	113.8	294.6	510.2
Greater than $1,000,000	2,414	146.4	3.4	7.4	19.0	53.8	173.5	394.0	602.1

Data source: ATSs, MBSD, RTRS

Panel B. Full effective spread by bond characteristics

		Number of Observations	Distribution of effective spread (in bps) Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Overall										
	Effective spread	166,417	225.8	–46.8	5.8	31.4	143.6	380.0	558.9	744.3
By bond characteristics										
Issue size	Less than $10M	45,003	164.8	2.0	7.9	22.0	68.4	270.1	448.9	537.3
	Between $10M and $50M	44,729	237.0	–6.4	8.6	35.4	170.2	394.0	541.9	706.4
	Greater than $50M	72,049	254.9	–137.4	–3.9	46.0	181.5	421.3	638.6	870.0
Credit quality	Investment grade	133,948	209.2	–13.7	7.2	29.2	131.8	363.7	512.4	628.9
	High yield	26,427	325.7	–299.8	–34.4	63.6	233.1	533.1	894.9	1,227.1
Maturity at issuance	Less than 1 years	25	10.8	0.2	0.5	2.8	7.0	17.9	24.1	27.1
	1 year to 10 years	16,614	106.7	–65.8	0.6	14.8	53.5	157.5	285.4	399.1
	Greater than 10 years	149,777	239.1	–41.9	7.3	35.6	163.3	400.0	572.9	767.4
Time since issuance	Less than 6 months	22,981	208.6	3.1	10.5	30.7	130.0	401.2	487.2	555.5
	Between 6 months and 5 years	57,795	217.0	–79.7	4.3	28.2	128.0	356.2	585.6	780.0
	Greater than 5 years	60,646	236.4	–116.7	2.2	31.3	139.3	357.5	659.9	949.2
Bond type	Revenue bond	57,642	238.8	–73.9	5.1	35.0	160.9	401.3	578.3	783.6
	GO bond	46,173	178.6	–25.7	5.2	24.9	98.0	281.5	476.3	610.2
Complexity features	Two or more complex features	138,693	239.7	–41.6	7.4	36.5	167.8	402.6	569.6	755.3
	Less than two complex features	27,724	156.3	–64.7	2.3	18.4	71.4	214.1	434.7	661.0

Data source: ATSs, DataScope, MBSD, RTRS

Table A3. Price improvement and markups (excluding RBW)

Table A3 reports the distribution of price improvement measures for municipal bonds at the issue-day level. Panel A reports the distribution of price improvement to the quote prices when two-sided quote exist, broken out by interdealer and customer trades and across different trade sizes for customer trades and interdealer trades, respectively. When two-sided quotes are available, price improvement is defined as (trade price – best bid)/(midpoint of the best bid and offer prices) for customer-sell trades and seller-initiated interdealer trades, and (best offer – trade price)/(midpoint of the best bid and offer prices) for customer-buy trades and buyer-initiated interdealer trades. Panel B presents markups for customer trades when only one-sided quotes are available at the time of trade execution. The markups are defined as (trade price – best offer price)/best offer price for customer-buy trades and (best bid price – trade price)/best bid price for customer-sell trades.

A. Price improvement for customer and interdealer trades with two-sided quotes

	Distribution of price improvement (in bps)								
	Number of Observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Overall									
All trades	166,417	–24.0	–231.8	–200.8	–105.3	–5.4	8.5	92.8	210.3
Customer trades	86,497	–53.3	–258.1	–227.6	–181.1	–90.8	0.0	146.5	311.8
Interdealer trades	79,920	7.7	–73.1	–38.9	–7.4	0.0	11.6	54.6	118.4
Customer trades by trade size									
Less than $25,000	35,683	–64.7	–261.5	–229.7	–191.1	–104.1	–0.3	132.6	282.8
Between $25,000 and $100,000	33,547	–66.8	–261.5	–223.5	–189.8	–103.9	–6.2	123.5	294.3
Between $100,000 and $1,000,000	14,288	–22.9	–241.3	–206.8	–136.4	–37.2	14.9	168.9	336.2
Greater than $1,000,000	2,979	88.6	–163.6	–86.1	–9.8	28.6	146.4	331.8	669.4
Interdealer trades by trade size									
Less than $25,000	25,999	10.5	–88.7	–47.2	–10.0	0.0	17.8	79.6	148.2
Between $25,000 and $100,000	30,913	7.6	–71.1	–38.6	–9.9	0.0	11.5	54.3	120.0
Between $100,000 and $1,000,000	20,594	4.9	–59.4	–28.9	–5.5	0.0	7.3	32.8	75.0
Greater than $1,000,000	2,414	4.7	–75.5	–38.7	–7.1	1.6	16.6	44.0	82.4

Data source: ATSs, RTRS

B. Markups for customer trades with one-sided quotes

	Distribution of markup to quote (in bps)								
	Number of observations	Average	5th percentile	10th percentile	25th percentile	Median	75th percentile	90th percentile	95th percentile
Customer trades	465,699	76.9	–67.0	–19.3	0.0	75.8	158.9	204.4	230.8
Buy trades	461,805	78.6	–57.9	–16.6	0.2	77.4	159.7	204.6	231.0
Sell trades	3,894	–115.9	–310.4	–310.4	–240.4	–85.2	–35.8	23.9	81.3
Customer-buy trades									
Less than $25,000	182,581	84.2	–80.2	–16.7	9.1	92.0	167.4	206.1	231.8
$25,000 - $100,000	192,399	101.5	–34.3	–8.3	8.4	91.4	168.9	209.2	236.1
$100,000 - $1,000,000	76,348	50.2	–56.4	–23.5	–0.4	22.3	116.3	189.0	215.7
Greater than $1,000,000	10,304	–46.0	–194.2	–90.6	–31.4	–7.3	9.2	75.8	135.8
Customer-sell trades									
Less than $25,000	1,515	–102.3	–310.4	–310.4	–216.5	–68.6	–19.9	50.0	99.4
$25,000 - $100,000	1,404	–133.4	–310.4	–310.4	–263.0	–96.9	–50.5	2.5	39.4
$100,000 - $1,000,000	820	–115.7	–310.4	–310.4	–213.1	–88.3	–38.5	0.0	21.7
Greater than $1,000,000	155	–90.	–310.4	–310.4	–310.4	–113.2	0.0	303.4	303.4

Data source: ATSs, RTRS