Quote Competition in Corporate Bonds

TERRENCE HENDERSHOTT, DAN LI, DMITRY LIVDAN,
NORMAN SCHÜRHOFF, KUMAR VENKATARAMAN*

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*We thank Laks Narayan, Paul Faust, Melissa Werring, and in particular, Chris White, for providing the data and for comments. Terrence Hendershott is with the Walter A. Haas School of Business, University of California, Berkeley, Berkeley CA 94720. Tel.: (510) 643-0619; fax: (510) 643-1412; e-mail: hender@haas.berkeley.edu. He provides expert witness services to a variety of clients. He has taught a course for a financial institution that engages in liquidity provision and high frequency trading activity. He gratefully acknowledges support from the Norwegian Finance Initiative. Dan Li is with the Board of Governors of the Federal Reserve System, Washington, DC. E-mail: dan.li@frb.gov. She has no conflict of interest to disclose. The views of this paper do not represent the views of the Federal Reserve Board. Dmitry Livdan is with the Walter A. Haas School of Business, University of California, Berkeley, Berkeley CA 94720. fax: (510) 643-1412; e-mail: livdan@haas.berkeley.edu. He is also a Research Fellow of the CEPR and has no conflict of interest to disclose. Norman Schürhoff is with the Faculty of Business and Economics and Swiss Finance Institute, University of Lausanne, CH-1015 Lausanne, Switzerland. Tel.: +41 (21) 692-3447; fax: +41 (21) 692-3435; e-mail: norman.schuerhoff@unil.ch. Schürhoff is also a Research Fellow of the CEPR. He gratefully acknowledges research support from the Swiss Finance Institute and the Swiss National Science Foundation under SNF project #100018_192584, "Sustainable Financial Market Infrastructure: Towards Optimal Design and Regulation" and has no conflict of interest to disclose. Kumar Venkataraman is with the Cox School of Business, Southern Methodist University, Dallas, TX 75275. E-mail: kumar@mail.cox.smu.edu. Venkataraman is a visiting economist at the Office of Chief Economist at FINRA, and acknowledges financial support for other projects.

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Abstract

Using data on indicative quotes dealers provide to clients, we establish empirical relationships regarding quote competition in the corporate bond market. Market-wide higher quoting activity is associated with greater trading volume and lower trading costs. At the dealer level, quoting dealers attract order flow with more and better quotes attracting more volume. These effects are larger when uncertainty is higher in terms of lower credit ratings and higher volatility, including the onset of Covid-19. Quote competition for order flow is associated with improved execution as clients receive better prices when more dealers quote and when clients trade with better quoting dealers. Our results are consistent with quote competition playing an important role in corporate bond trading.

JEL Classification: G12, G14, G24

Key words: Pre-trade transparency, quotes, corporate bonds, OTC markets, order flow competition

1 Introduction

Fixed income securities such as corporate bonds are typically traded over-the-counter (OTC) (Bessembinder, Spatt and Venkataraman (2020)). OTC markets are considered to be opaque with limited or no pre-trade transparency (Weill (2020)), as information on the best available bid and ask quotes are not widely available. Corporate bond dealers do disseminate indicative quotes on a subset of bonds (called "runs") to potential institutional customers. However, less-sophisticated participants, such as retail investors, have limited direct access to dealer quotes. The lack of consolidated quotes in bond markets implies that many participants do not see the best available prices. Thus, a dealer offering a good quote might get passed over for order flow that goes to competitors offering inferior quotes. This discourages the better quotes from being offered in the first place (Godek (1996)). Madhavan and Dutta (1997) provide a formal model of how better quotes failing to attract order flow lessens quote competition. If dealer quotes are unrelated to which dealers receive order flow and the prices at which they trade with customers, then customers must search across dealers to find the best prices, as in many theoretical models of OTC markets.

In this study, we provide novel empirical evidence on the extent of quote competition in the corporate bond market: First, we ask if higher quoting activity is associated with higher trading activity in aggregate? Second, is individual dealers' quoting activity associated with a higher propensity to trade? If so, does higher quote quality (better prices quotes) attract more order flow, and further, what are the determinants of order flow sensitivity to quotes? Third, do investors benefit from quote competition? Does quote quality affect customer's trading costs? And fourth, how did the market-wide Covid-19-related uncertainty affect quoting behavior, quote competition, and customers' trading costs? Consistent with quote competition, we find that quotation activity and quality are positively associated with higher trading volume and lower trading costs. This relation is stronger when uncertainty is higher. At the onset of the Covid-19 pandemic, quoting activity sharply declines and trading costs sharply increase.

While the literature on OTC markets generally does not consider dealer quotes, Duffie, Dworczak, and Zhu (2017) theoretically examine pre-trade transparency in OTC markets in the form of a single market-wide benchmark.[1] If individual dealer quotes are informative about potential terms of trade then quotes provide pre-trade transparency beyond a benchmark by fostering quote competition. The importance of quote competition has been studied in equity markets, particularly in research on Nasdaq prior to the 1990s reforms.[2] Christie and Schultz (1994), Godek (1996), Huang and Stoll (1996), and Barclay, Christie, Harris, Kandel, and Schultz (1999), among others,

[1]Cereda, Chague, De-Losso, and Giovannetti (2021) examine the introduction of a benchmark in the Brazilian stock lending market.

[2]Cao, Ghyssels and Hatheway (2000) study price discovery via indicative quotes by Nasdaq dealer prior to the official opening of the regular trading day. Stoll and Schenzler (2006) examine how firm Nasdaq quotes were in general. Bessembinder (2003) examines quotes competition in NYSE-listed stocks across exchange while Boehmer, Saar and Yu (2005) examine competition among traders on the NYSE via the introduction of NYSE's OpenBook service that provides limit-order book information to off-exchange traders. Battalio, Hatch, and Jennings (2004) examine quote competition among option exchanges.

examine the importance of better quotes attracting order flow for competition on Nasdaq.[3] In the Nasdaq market that Barclay et al. (1999) studied, best execution obligations required dealers to execute equity trades at the best quoted prices by other dealers. Bessembinder at al. (2020) note that such best execution requirements do not exist in corporate bonds, potentially further reducing the incentives for quote competition. Harris (2015) examines quotation data consolidated across several electronic bond trading venues and shows that execution prices are often worse than the best quote, consistent with the lack of best execution.

We examine quote competition in corporate bonds by studying whether the decision to quote, the extent of quotations, and higher quality quotes attract order flow. Indicative quotes are emailed by dealers to customers in "runs" that consist of a list of bonds and the indicative quoted price or yield at which the dealer is willing to buy or sell each bond. Our data is from BondCliQ (CliQ, hereafter), a provider that collects quotes from participating dealers by requesting inclusion on each dealer's distribution list for runs. The CliQ data contains dealer names that we match to the dealer names in the regulatory TRACE dataset to link quoting and trading activity. While many of the largest dealers do not include CliQ on their runs during our October 2019 to May 2020 sample period, CliQ dealers provide significant liquidity, averaging about 25% of dealer-client trading volume in corporate bonds.

At the aggregate level, higher quoting activity by CliQ dealers is associated with higher trading volume. A trade is more likely to occur on bond-days with quoting activity, 40%, than on bond-days without quoting activity, 20.7%, with the difference, 19.2%, being highly significant. In regression specifications that account for bond attributes, market conditions, and trade persistence, the presence of a quote increases the number of trades in the bond by 17% to 23% and doubling the number of quotes translates into a 14% to 19% increase in the number of trades. We also find that the CliQ dealers' market share of aggregate trading is higher on bond-days when they quote. A doubling of the number of CliQ-dealer quotes increases CliQ dealers' market share by 1.8 percentage points.

Having established that in aggregate CliQ dealers trade more when they quote more, we next examine quote competition at the individual dealer level for all participating CliQ dealers. On average each CliQ dealer trades in a bond on 4.1% of days. In regressions with bond, dealer, and day fixed effects, the increase in trade probability due to quoting by the same dealer in the same bond is 4.0% (the extensive margin), an almost 100 percent increase from the unconditional average, and increases the number of trades by the quoting dealer by 3.6% (the intensive margin). Along similar lines, when the number of quotes increases from one to two, which is the median number of quotes per dealer-bond-day, the increase in trade probability is 4.9% and the increase in number of dealer's trades is 4.5%.

We next move beyond whether a dealer quotes and how often they quote to the competitiveness

[3] Barclay et al. (1999) note that "dealers could not obtain this order flow by competing more aggressively using quoted prices ... dealers [] faced a disincentive to improve the posted quotes, for they would likely fail to attract significant new order flow but would reduce the profits on [] orders that they (and other dealers) were already receiving."

of their quotes. We measure competitiveness of a dealer's quote relative to the average or the best quote across all dealers in a bond on that day, which we refer to as quote quality. We find that the quote quality of a dealer impacts both dealer's extensive and intensive margins of trading after controlling for the presence of the dealer's quote, the total number of dealers posting a quote and trade persistence. Economically, a one standard deviation improvement in a dealers' quote quality, 22 bps, increases trade probability at the dealer-bond-day level by 9.65% and increases the number of dealers' trades by 0.5%. We also find that order flow respond more to quote activity when VIX is high (including the onset of Covid-19) and for speculative grade bonds, both pointing to uncertainty as an important driver of the relationship.

The natural underlying mechanism for quotes attracting order flow is that customers receive better execution prices when trading with dealers with better quoted prices. The relation between quote and trade prices also provides evidence on how firm are the indicative quotes. If quotes are not at all firm then there should be no relation between the price a dealer quotes and the price at which a dealer trades. If quotes are perfectly firm then differences in quoted prices should completely explain difference in transaction prices. We find that 45% of the quote quality is passed through to prices received by clients. This suggests that quotes are meaningfully firm and that quote quality affects client execution quality.

We find that quotation activity can improve trade prices for a client even when the dealer with whom the trade is consummated is posting a bad quote. Client execution quality is higher on bond-days when dealers provide quotes relative to days without quotes. Further, average quote quality of all dealers, not just the dealer executing the trade, matters for execution prices. We show that dealers with bad quotes improve transaction prices over their quotes more than dealers with good quotes. Overall these results suggest that dealers respond to other dealers' quotes, consistent with quote competition, and that customers benefit from the competition among dealers.

Trading and quoting are not frequent in corporate bonds, so much of our analysis is done daily. A concern with this level of aggregation is that unobserved factors could affect both trading and quoting in a bond on a certain day, thus limiting the ability to establish a casual link. However, the within CliQ-dealer analyses in linking trading activity to whether a dealer quotes, how often a dealer quotes, and how aggressively a dealer quotes establish that unobserved factors that could potentially affect both trades and quotes would need to be active at the bond-dealer-day level, not just the bond-day level. Similarly, the results for quote quality, which is a relative measure of a dealer's quote versus other dealers' quotes on a bond-day, should not be affected by unobserved bond-day factors because these affect all dealers.

To help demonstrate causality, we separately examine the relation between quote quality and order flow for large trades (trade size $\geq$ \$100K) and small trades (trade size $<$ \$100k). Because retail customers do not directly receive CliQ quotes, we expect that, if quote quality attracts order flow, the relation should be stronger for institutional trades than retail trades. Indeed, we find for small trades that quote quality does not impact the extensive and intensive margin of trading, while for large trades, the impact is statistically and economically significant. We find that uncertainty affect the sensitivity of institutional order flow to quotes but not the sensitivity of retail order flow to quotes. Further, quote quality improves client execution quality for large trades, where about 51% of quote quality is passed through to the trade price of clients, but not for small trades. Thus, potential unobserved factors would need to be active at the bond-dealer-day level for large trades, but not for small trades, to explain the asymmetry.

Our second approach to show causality exploits the pattern that dealer runs occur in the morning while trading peaks in the afternoon. Here we split the trading day into the morning and afternoon session and examine the lead-lag relationship between quotes and trades. We find that a dealer's trading in the afternoon is higher when the dealer quotes more in the morning after controlling for the dealer's trading activity in the morning.

Our study provides new empirical evidence on the state of quote competition in the corporate bond market. Dealers use indicative quotes to broadcast their desire to trade a list of bonds. Trading activity exhibits a strong association with quoting activity, suggesting that institutional clients direct order flow in response to dealers' signals of trading interest. Better quality quotes are associated with greater trading activity, suggesting that customers route orders to the dealer posting a better quote. Importantly, better quoted prices are passed through to trade prices received by clients. Thus, consistent with quote competition, dealers have the incentives to post a better quote and customers have incentives to route their orders to dealers quoting better prices.

Our results that institutional clients benefit from quote competition in the form of lower trading costs point to the importance of broader availability of the best bid and ask quotes. Green, Hollifield and Schürhoff (2007) predict that fragmentation and lack of transparency create opportunities for dealers to profit from less-sophisticated investors. Consistent with this, the literature has shown that smaller trades have higher trading costs than larger trades in corporate bonds.[4] Future research should consider the implications of our results for market design, i.e., whether the wider availability of dealer quotations should arise endogenously in the market place, or whether it is necessary for a regulator to mandate pre-trade transparency. We discuss these issues in our concluding section.

Our study is related to the literature on pre-trade transparency in electronic bond platforms. The majority of electronic trading occur on request-for-quotations (RFQs) venues, where dealers respond with firm quotes to a client's enquiry. One distinction is that dealer quotes on RFQs are shown only to the enquiring client while dealers "runs" are broadcast more broadly to all potential institutional customers. Hendershott and Madhavan (2015) show that RFQ usage is higher for recently issued, investment grade, large-issue-size bonds while O'Hara and Zhou (2021) conclude that electronic trading improved the market for both customers and dealers. Some studies (e.g., Harris (2015), Kozora et al. (2020), Kim and Nguyen (2021)) have examined dealer quotation data

[4] See, among others, Schultz (2001, 2017), Bessembinder, Maxwell and Venkataraman (2006), Edwards, Harris and Piwowar (2007), Goldstein, Hotchkiss and Sirri (2007), Friewald, Jankowitsch and Subrahmanyam (2012), Hendershott, Li, Livdan and Schürhoff (2020), Bessembinder, Jacobsen, Maxwell and Venkataraman (2018), Bao, O'Hara and Zhou (2018), Trebbi and Xiao (2019).

from corporate bond ATS venues. As O'Hara and Zhou (2021) note, electronic trading remains fairly small and segmented, catering mainly to retail clients and smaller institutional trades, while the traditional OTC dealer market dominates trading in the round lot of $1 million or more.

The remainder is organized as follows. Section 2 describes the data and provides summary statistics. Section 3 explores if dealer quotes attract trades. Section 4 shows that more aggressive dealer quotes increase order flow. Section 5 explores if and when dealer quotes improve client execution quality. Section 6 documents the intraday lead-lag relation between quotes and trades. Section 7 concludes.

2 Data

Our bond quotes are from BondCliQ, a company trying to create a centralized, consolidated quote system for U.S. corporate bonds. The sample covers the period from October 1, 2019 to May 1, 2020, including the period of stress in the fixed-income markets at the onset of the Covid-19 pandemic.

The raw quote data contains 8.5 million quotes (bid or ask) on roughly 24,000 bonds. We rely on the Mergent Fixed Income Securities Database (FISD) data to identify securities that are corporate bonds with known features, and thus require the bond to be in the FISD. We then apply a series of filters to select bonds with well-defined features relating to bond type, optionality, offering date, offering size, maturity date and coupon type. Table A.1 in the Appendix details the steps involved in filtering the BondCliQ data on dealer quotes. After filtering, 4,160,948 quotes on 8,077 bonds remain. Since bid-side quotes and ask-side quotes are often quoted by the same dealer for the same bonds at the same time, we can collapse the sides of the quotes and call each unique quote by the same dealer on the same bond at a unique timestamp a "run". This yields 2,462,193 run observations (one-sided or two sided). Each quote is in terms of absolute *price* or as a *spread* from the Treasury benchmark yield, and sometimes in both. We convert quotes in spread to prices when only the spread is available. The details of this procedure are documented in Appendix B.

Bond transaction data are supervisory TRACE from FINRA. The supervisory TRACE data contains unmasked dealer IDs that allow us to link quotes to trades of the same dealer. We apply similar filters in terms of bond characteristics to the TRACE data. In addition, since we are mainly interested in comparing quoting behavior and trading behavior of the same dealer, in the main analysis in the paper, we further narrow our trade sample to trades that involve at least one CliQ dealer[5]. This yields a sample of 884,030 trades on 9,168 bonds.

Our final data combines the quotes and trade data and include a total of 9,617 bonds that have either been quoted or traded by one of the 35 CliQ dealers over 146 trading days. We maintain two versions of this data, one at the micro-level with each quote and trade as a unique observation

[5]For trades between client and dealer, this means the dealer is one of the 35 CliQ dealer firm. For interdealer trades, at least one side need to be a CliQ dealer.

Panel A: Quoting and trading prior to Covid-19 Panel B: Quoting and trading during Covid-19

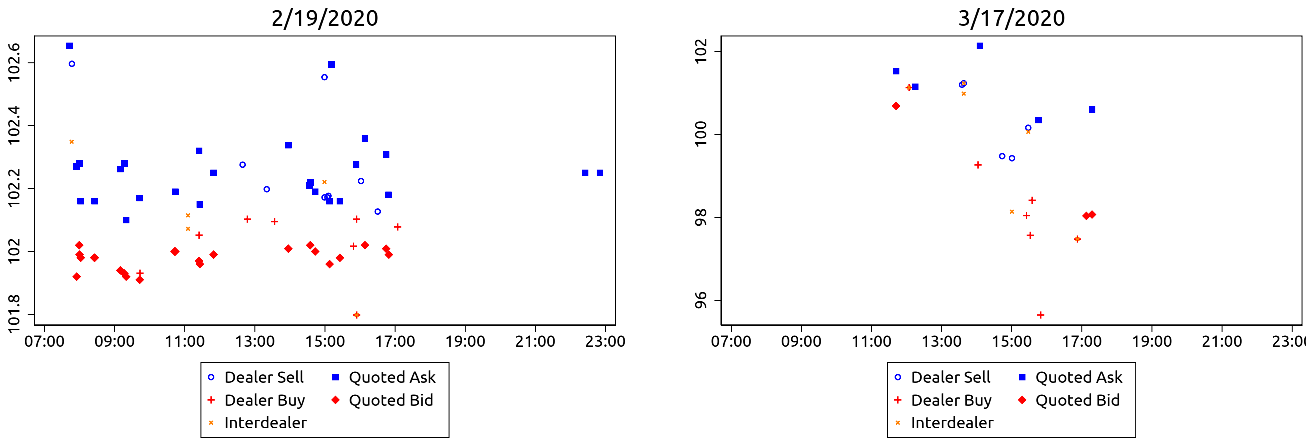

Figure 1: Illustrative examples of quotes and trades

The figure provides illustrative examples of quotes and trades for a single bond and two selective trading days during the sample period. We illustrate by different markers all individual dealer bid quotes, ask quotes, buy trades, sell trades, and interdealer trades during the trading day.

and another version collapsed at the dealer-bond-day level. The latter is a panel dataset, where the panel is identified through unique combinations of dealer-bond pairs in the quote and trade data. We set the variables that capture trading or quoting activity to zero on days without any quote or trade, to create a balanced panel.

CliQ dealers are mid-tier dealers in the corporate bond market. The largest CliQ dealer ranks among top 10 of all TRACE dealers by trading volume, while 19 CliQ dealers rank among top 50 of all TRACE dealers. The daily market share of all CliQ dealers averages about 25% of the total TRACE (dealer to client) volume with the range spanning 15% to 40% depending on the calendar day. There is no significant change in the daily market share of CliQ dealers during late March 2020.

Using the precise timestamp for each quote, we are able to infer the set of bond quotes sent in the same run message by the dealer to the clients. As shown in Table 1, a median message contains 7 bonds, but vary substantially across dealers and across days. At the 5% and 95% tails, a message contains 1 and 42 bonds respectively. Dealers send out many of these lists of quotes throughout the day. The frequency that dealers send out such messages also vary substantially across dealers and across days. A median dealer sends out 13.5 such messages a day. At the 5% and 95% tails, dealers send out 1 and 236 such messages a day, respectively.

Figure 1 presents an illustrative example of quoting and trading activities for the same bond on two different days, a normal day on February 19, 2020 before the onset of the pandemic, and a "crisis" day on March 17th, 2020. The figure graphs quoted asks (squares)/bids (rhombuses), dealer buys (pluses)/sells (circles), and interdealer trades (crosses). Panel A of Figure 1 shows active quoting and trading activities, with traded prices typically within bid/ask quotes. The majority of quotes are two-sided. Panel B of Figure 1 paints a different picture. There are substantially fewer trades and quotes, and quotes are more likely to be one-sided. Seven dealer buys take place during the day with six of them at prices below the opening bid quote. Overall, for the same bond, we see many quotes and trades with limited price dispersion on a pre-Covid-19 trading day and very few quotes and trades with large price dispersion on a Covid-19 trading day.

2.1 Measuring quoting and trading activity and quality

Our main variables of interest relate to the extensive and intensive margins of quoting and trading activity, the quality of a dealer's quoted prices relative to other dealers, a dealer's price improvement over quoted prices, and client execution quality.

To characterize the extensive margins of quoting and trading activity we construct for dealer i and bond j the quote indicator HasQuote_{ijt}, which is one if the dealer quotes the bond on day t and zero otherwise, and the trade indicator, HasTrade_{ijt}, which is one if the dealer trades the bond on day t and zero otherwise:

$$\text{HasQuote}_{ijt} = \begin{cases} 1, & \text{if dealer } i \text{ quotes bond } j \text{ on day } t, \\ 0, & \text{otherwise,} \end{cases} \tag{1}$$

and

$$\text{HasTrade}_{ijt} = \begin{cases} 1, & \text{if dealer } i \text{ trades bond } j \text{ on day } t, \\ 0, & \text{otherwise.} \end{cases} \tag{2}$$

To characterize the intensive margins of quoting and trading we construct the natural log-transformed number of quotes, LogNoQuotes_{ijt}, and trades, LogNoTrades_{ijt}, by dealer i in bond j on day t, respectively, where we add one to the number under the log to make these measures well-defined when the number of quotes or trades, or both, is zero.

Next, we define quote and trade characteristics relevant for our study. Let BidQuote_{ijt} and AskQuote_{ijt} be the average quoted prices of bond j on day t at which dealer i indicates a willingness to buy and sell, respectively. $\text{BenchmarkBidQuote}_{jt}$ and $\text{BenchmarkAskQuote}_{jt}$ are benchmark quotes derived from the quotes of all dealers in bond j on day t. We use two alternative benchmarks in the empirical implementation: the average dealer ask or bid quotes (our baseline quote quality measure) and the best offer (BO) or best bid (BB). We define the bid and ask quote quality of dealer i in bond j on day t relative to the quotes of all other dealers in the same bond on the same day:

$$\begin{cases} \text{BidQuoteQuality}_{ijt} = \text{BidQuote}_{ijt} - \text{BenchmarkBidQuote}_{jt}, \\ \text{AskQuoteQuality}_{ijt} = \text{BenchmarkAskQuote}_{jt} - \text{AskQuote}_{ijt}. \end{cases} \tag{3}$$

Our $\text{QuoteQuality}_{ijt}$ measure is defined as the average of the bid-side quote quality and ask-side quote quality. When one side is missing, we use the side that is not missing.

We define client execution quality with dealer i in bond j on date t in terms of the transaction cost that the client faces on the trade. Lower transaction costs are tantamount to better client execution quality. To compute client execution quality, we compare the traded price to a benchmark price:

$$\text{ClientExecutionQuality}_{ijt} = \begin{cases} \text{Price}_{ijt} - \text{BenchmarkPrice}_{jt}, & \text{for dealer buy trades,} \\ \text{BenchmarkPrice}_{jt} - \text{Price}_{ijt}, & \text{for dealer sell trades.} \end{cases} \quad (4)$$

We use two alternative proxies for the benchmark price on the transaction. In our base case, we define $\text{BenchmarkPrice}_{ijt}$ as the Bank of America Merrill Lynch (BAML) end-of-day quote on the same bond on the day prior to the transaction.[6] Alternatively, following Hendershott and Madhavan (2015), we define $\text{BenchmarkPrice}_{ijt}$ as the price on the last interdealer trade prior to the transaction. We require the last interdealer trade to be no more than 3 calendar days before the trade.[7]

Finally, we construct a price improvement measure to capture improvement of trade quality over the last available quote. We first match each trade to the last quote by the same dealer on the same day for the same bond on the same side of the trade. We require that the quote arrives before the trade. Roughly 8% of all trades can be matched to a quote. For each quote-trade pair, we define $\text{PriceImprovement}_{ijt}$ depending on whether it is a dealer sell or buy:

$$\text{PriceImprovement}_{ijt} = \begin{cases} \text{Price}_{ijt} - \text{BidQuote}_{ijt}, & \text{for dealer buy trades,} \\ \text{AskQuote}_{ijt} - \text{Price}_{ijt}, & \text{for dealer sell trades.} \end{cases} \quad (5)$$

A positive $\text{PriceImprovement}_{ijt}$ means that the client executed at a price better than the last available quote.

2.2 Descriptive statistics about individual dealer quotes and trades

Most of our analysis is conducted on quotes and trades at the dealer-bond-day level. The information on quotes is limited to the BondCliQ, or simply CliQ, dealers and for each quote it consists of the time stamp, quoting dealer ID/name, quoted price (either bid or ask) if quote is one-sided or both bid and ask prices if quote is two-sided, bond CUSIP number, and the quantity for some quotes. We use all trades, both by CliQ and non-CliQ dealers, which we obtain from FINRA supervisory TRACE and match it to CliQ data by the dealer ID and bond CUSIP number. For each trade

[6] Because BAML end-of-day quotes are available only for the bid side, we add 15bps (equal to half of the sample average effective spread) to the benchmark level to make the bid- and ask-sides comparable. Hendershott et al. (2020) provides a detailed description of BAML quotes.

[7] In equity markets, researchers use the average of the prevailing bid and offer price at the time of the trade as the benchmark price. However, the information on the direction of the trade (i.e., whether the trade was initiated by a buyer or seller) is not available and must be imperfectly inferred from the available data.

Table 1: Descriptive statistics

The table provides descriptive statistics about individual dealer quotes and trades, the number per day, frequency, quality, and intraday timing. Variables with (w) are winsorized at 0.5% and 99.5%.

	N	Mean	SD	5%	25%	50%	75%	95%
				Panel A: Quotes by CliQ dealers				
No. dealers quoting per day	146	27.03	2.75	22	26	27	29	31
No. dealers quoting per day per bond	631,435	1.93	1.23	1	1	2	2	4
No. bonds quoted per day	146	4,324.90	950.95	2,499	3,781	4,711	5,034	5,387
No. bonds quoted per day per dealer	3,946	309.62	412.08	6	41	153	413	1,171
No. bonds quoted per message	179,531	13.71	25.57	1	3	7	16	42
No. messages per day per dealer	3,946	45.50	81.58	1	5	13.50	40	236
Quote time-of-day (hour)	2,462,193	10.64	3.10	7.25	8.32	9.85	12.57	16.42
Quoted bid-ask spread (w)	1,931,288	0.74	0.65	0.09	0.26	0.56	1.00	2.00
Quote quality (w):								
BenchmarkQuote = Avg. quote_{jt}	1,098,617	-0.00	0.13	-0.21	-0.01	0.00	0.02	0.18
BenchmarkQuote = Best quote_{jt}	1,098,617	-0.22	0.28	-0.76	-0.35	-0.12	0.00	0.00
				Panel B: Trades by CliQ dealers				
No. dealers trading per day	146	33.89	1.13	32	33	34	35	35
No. dealers trading per day per bond	363,006	1.54	0.92	1	1	1	2	3
No. bonds traded per day	146	2,486.34	336.13	1,859	2,356	2,548	2,683	2,862
No. bonds traded per day per dealer	4,948	112.85	164.91	2	14	44	138	536
Trade time-of-day (hour)	917,754	12.98	2.42	8.97	11.12	13.22	15.00	16.40
Client execution quality (w):								
BAML benchmark_{ijt}	417,512	-0.37	1.75	-2.87	-0.64	-0.15	0.13	1.43
Interdealer benchmark_{ijt}	452,235	-0.29	1.18	-2.00	-0.46	-0.08	0.03	0.81
$\text{PriceImprovement}_{ijt}$ (w)	40,844	0.07	0.75	-0.75	-0.04	0.03	0.19	0.89
				Panel C: Quotes and trades at dealer-bond-day level, balanced panel				
HasQuote_{ijt}	13,767,800	0.09	0.28	0.00	0.00	0.00	0.00	1.00
HasTrade_{ijt}	13,767,800	0.04	0.20	0.00	0.00	0.00	0.00	0.00
LogNoQuotes_{ijt}	13,767,800	0.08	0.30	0.00	0.00	0.00	0.00	0.69
LogNoTrades_{ijt}	13,767,800	0.04	0.19	0.00	0.00	0.00	0.00	0.00

we know the transaction price, trade direction, dealer buy/sell indicator, and bond characteristics. The balanced panel has a total of 13,767,800 observations.

Table 1 provides descriptive statistics about individual dealer quotes and trades. Results are presented separately for quotes (Panel A), CliQ trades (Panel B), and a balance panel of quotes and trades at the dealer-bond-day level (Panel C). We start with the quote data. On average, 27 dealers quote per day and 2 dealers quote per day per bond. The 95th percentile has 31 dealers quoting per day and 4 dealers quoting per day per bond. In the cross-section, the number of dealer firms quoting a bond on any given day is higher if the bond is larger at issuance, has higher credit

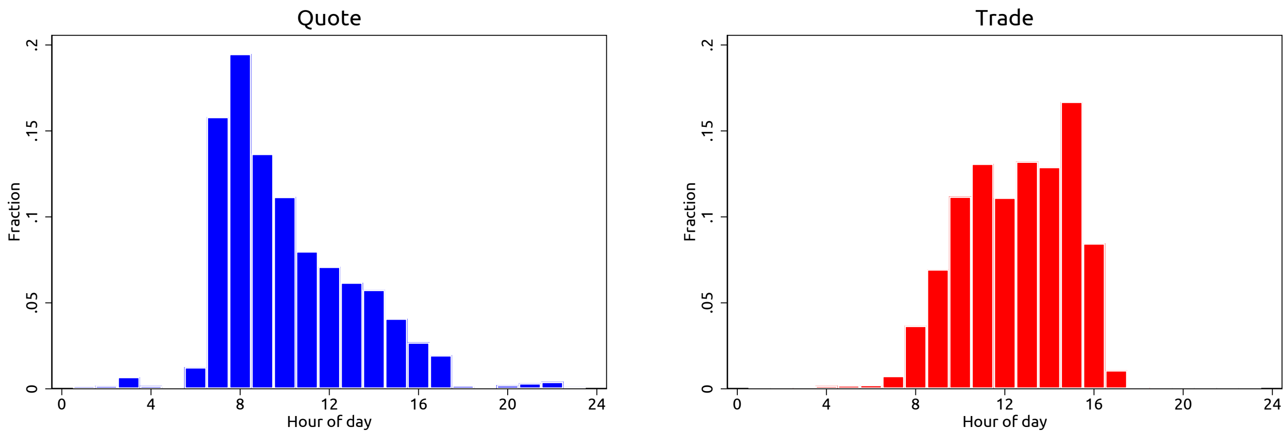

Figure 2: Distribution of quotes and trade during the day

The figure documents the distribution of trades and quotes during the day. We pool all dealer-bond-days and plot the fraction of the quotes (left) and trades (right) that arrive during a given hour.

rating, or is less seasoned. For the 5% most quoted bonds, the number of quoting dealers varies over time between less than five and more than 15. About 30% of the quotes are one-sided quotes with the bid side quoted less than the ask side, particularly during stressful periods.

On typical day, 4,711 bonds are quoted on CliQ and 153 bonds are quoted by a given dealer. At the 95th percentile, 5,387 bonds are quoted that day and 1,171 bonds are quoted by a dealer on a given day. The quoted bid-ask spread is winsorized at 0.5% and its average/median value is 74bps/56bps, and it can be as high as 2%. The average/median quote quality is -0bps/0bps (standard deviation of 13bps) when using the average quote as a benchmark, and it is -22bps/-12bps (standard deviation of 28bps) when using the best quote as a benchmark.

Panel B of Table 1 reports descriptive statistics for CliQ dealer trades. On average, 34 CliQ dealers trade per day. An average number of 1.54 CliQ dealers trade a given bond per day. The average/median client execution quality is -37bps/-15bps when using the BAML quote as a benchmark, and it is -29bps/-8bps when using the interdealer benchmark. A higher number indicates better client execution quality since it is associated with lower transaction costs. Finally, the average/median price improvement is 7bps/3bps. Price improvement ranges from -75bps (5th percentile) to 89bps (95th percentile).

Panel C of Table 1 reports descriptive statistics for quotes and trades for the pooled data in a dealer-bond-day balanced panel. The average value of $\text{HasQuote}_{ijt}/\text{HasTrade}_{ijt}$ is the unconditional probability of a quote/trade on a day in a bond by a dealer, which equals 9% for quotes and 4% for trades with standard deviations of 28% and 20%, respectively.

Panel A of Table 1 shows that quotes arrive on average in the morning hours, with a mean between 10AM and 11AM. The row for trade time-of-day in Panel B shows that trades take place on average in the afternoon hours, with a mean at about 1PM. Figure 2 documents the distribution of quotes and trades during the day. The left plot shows that quoting activity is naturally slow in

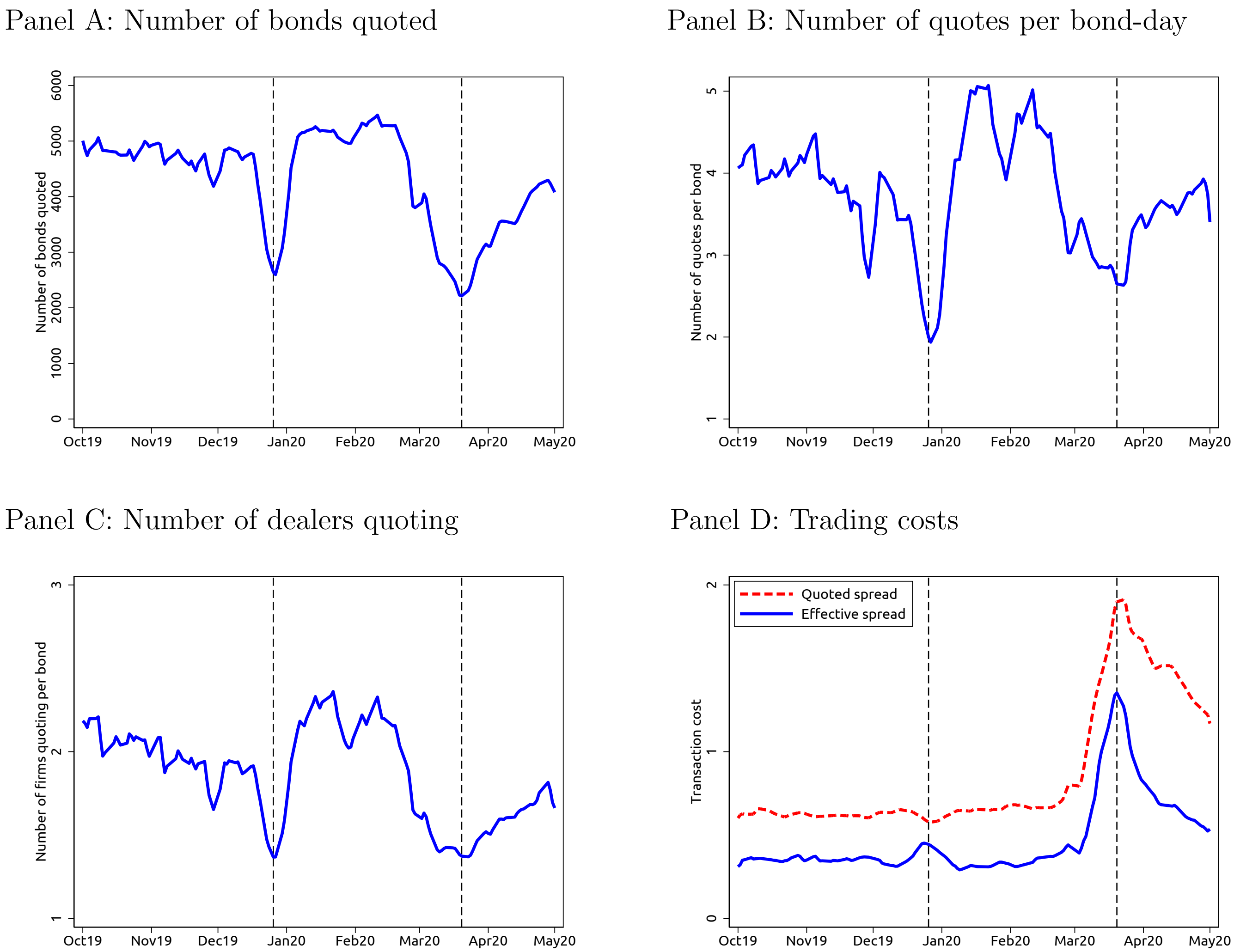

Figure 3: Times series behavior of quoting activity and trading cost

The figure documents the times series of quoting and trading activity. Each line corresponds to the daily sample average. The daily statistics are smoothed using a locally weighted regression. The dotted vertical lines correspond to December 26, 2019 and March 20, 2020, respectively.

the early morning. Quoting spikes up to 17% at 7AM right before trading starts to pick up (right plot). The peak of quoting activity is at 8AM when nearly 20% of all quotes arrives. Quoting activity gradually declines through the rest of the day and hits its lowest simultaneously with the lowest for trading activity at 6PM. Only around 3% of daily quotes arrive at 3PM when the highest fraction of trades takes place. The right plot shows that trading is slow between 4AM and 8AM, then it picks up and plateaus at about 12%-13% of daily trades, staying at this level until 3PM when the fraction of daily trades jumps to its highest value of 17%, before declining dramatically after 4PM. These results are indicative of the lead-lag intraday relation between quotes, which lead, and trades, which lag. We next examine the quoting activity over our sample period.

Quoting activity over time: Figure 3 provides univariate evidence on quoting activity over time.[8] Panel A of Figure 3 documents the time series of the daily average the number of quoted bonds. One notable observation is that the average number of quoted bonds, the extensive margin of quoting, the average number of daily quotes per bond in Panel B of Figure 3, the intensive margin of quoting, and the average number of dealers quoting in Panel B of Figure 3 are all decline around year end, bottoming out on December 26, 2019, and then rebound back to their pre-holiday levels. Excluding the holiday period, the average number of quoted bonds ranges between 4,500 in late November 2019 and 5,500 in mid-February 2020. The number of quoted bonds starts declining in late February 2020 right after CDC declares Covid-19 is heading toward pandemic status on February 25, 2020. It hits its lowest number on March 20, 2020, when Federal Reserve expands its program of support for flow of credit, and then starts climbing back up, reaching around 4,300 in early May 2020.

Panel B of Figure 3 graphs the daily sample average number of quotes per bond. Between October 2019 and late December 2019, the daily average number of quotes per bond fluctuates between 2.8 and 4.5. Quotes rebound to 5 quotes in mid-January 2020, and then decline to 4.5 quotes by late February 2020. As with trades, quotes steadily decline with the onset of Covid-19, bottoming out at 2.8 quotes on March 20, 2020. Note, that this number is still larger than the number of quotes, 2, on December 26, 2019. The number of quotes per bond slowly increases between March 20, 2020 and late April 2020, reaching 3.5 quotes. Panel C of Figure 3 plots the daily sample average number of dealers quoting per bond. Following a time trend as in Panels A and B, the average number of quoting dealers declines from 2.2 in October 2019 to 1.9 in late December 2019, and drops sharply to 0.4 during 2019 New Year holidays. Quoting dealers rebounds to its sample high value of 2.5 dealer in late January 2020, and then declines to 0.4 dealers by March 20, 2020. The average number of quoting dealers slowly increases between March 20, 2020 and late April 2020, reaching the value of 1.7.

Panel D of Figure 3 plots the average quoted spread (quoted ask minus quoted bid, dashed line) and effective spread (the negative of the sum of customer buy quality and customer sell quality, solid line).[9] With the exception of the period around the 2019 New Year holidays, both the effective and quoted spreads are quite flat between October 2019 and March 2020, approximately 40bps and 60bps, respectively. Both spreads rise sharply in the onset of Covid-19 in March 2020, and peak on March 20, 2020 at 1.5%, effective spread, and 1.9%, quoted spread. After peaking the spreads decline sharply to 50bps for the effective spread and 1.3% for the quoted spread.

Overall, there exists variation in the daily average number of quotes per bond and dealers quoting. Both quantities are procyclical and positively related to liquidity. In the next section we investigate the link between quoting and trading in more depth.

[8]Figures C.1 and **??** in the Appendix provide additional time series evidence on quoting activity.
[9]This is equivalent to the difference between average dealer sell prices and dealer buy prices.

3 Do dealer quotes attract trades?

Dealers' quoting activity can reduce the clients' search costs by directing them to dealers who compete via quoting to signal their willingness to trade. Such quote competition relies on dealer quotes attracting trades, which we investigate in this section. We first document this relation at the aggregate level and then at the individual dealer level.

3.1 Aggregate effect of quoting on trading activity

We start analyzing quote competition between CliQ dealers and non-CliQ dealers. While we do not observe quoting by non-CliQ dealers, we can study whether aggregate trading activity, CliQ-dealer trading, and the market share of CliQ dealers increase when CliQ-dealer provide quotes.

Univariate analysis: Here we estimate the probability of having a trade depending on quoting activity in the same bond on the same day. To do this, we construct for bond j the trade indicator HasTrade_{jt}, which is one if bond j is traded on day t and zero otherwise. Summing this indicator over t and dividing the sum by the total number of trading days yields the unconditional daily probability of trading for bond j. Averaging this probability across all bonds yields the sample average unconditional daily probability of trade in the same bond, which we report. To calculate daily trade probabilities conditional on quoting and not quoting we construct indicators HasQuote_{jt}, which is one if bond j is quoted on day t and zero otherwise, and NoQuote_{jt}, which is one if bond j is not quoted on day t and zero otherwise. To obtain the daily trade probability in the same bond on the same day conditional on having/not having a quote in it, we follow the same procedure used to calculate the average unconditional daily probability but for the trade indicator interacted with $\text{HasQuote}_{jt}/\text{NoQuote}_{jt}$. We also examine trade size by splitting the sample into small, Par<\$100K, and large, Par≥\$100K, trades, and we control for credit risk by splitting the sample into investment grade (IG) and high yield (HY) bonds, where we take the daily ratings for IG (AAA to BBB-) and HY (BB+ and below or missing) from BondCliQ.

Panel A of Table 2 reports these results. Several findings stand out. First, a trade is almost twice as likely to take place on days with quoting activity, 40%, than on days without quoting activity, 20.7%, with the difference, 19.2%, being significant at 1% level. Second, large/small trades are also more likely to take place on days with quoting activity, 24.8%/26.0%, than on days without quoting activity, 12.0%/12.6%, with the difference, 12.7%/13.3%, being significant at 1% level. Finally, IG/HY bonds are more likely to be traded on days with quoting activity, 39.5%/46.1%, then on days without quoting activity, 19.0%/22.7% with the difference, 20.5%/23.4%, being significant at 1% level. Overall, these results support quoting facilitating trading at the aggregate level. We use multivariate analysis to further understand the link between quoting and trading.

Table 2: Aggregate and individual quoting and trading activity

The table documents the relationship between aggregate and individual dealers' quoting activity and trading activity. In Panel A, we aggregate quotes and trades across dealers. In Panel B, we disaggregate quotes and trades across dealers. Standard errors are robust to heteroskedasticity. Significance levels are *** 1%, ** 5%, * 10%.

Panel A: Probability of trade in bond j on day t					
	N	All bond-days	NoQuote_{jt}	HasQuote_{jt}	Δ
HasTrade_{jt}	1,406,564	29.4%	20.7%	40.0%	19.2%***
Trade size≥\$100K	1,406,564	17.8%	12.0%	24.8%	12.7%***
Trade size<\$100K	1,406,564	18.6%	12.6%	26.0%	13.3%***
IG rated	987,307	31.1%	19.0%	39.5%	20.5%***
HY rated	419,257	25.4%	22.7%	46.1%	23.4%***
Panel B: Probability of trade by dealer i in bond j on day t					
	N	All dealer-bond-days	NoQuote_{ijt}	HasQuote_{ijt}	Δ
HasTrade_{ijt}	13,767,800	4.1%	3.9%	5.7%	1.8%*
Trade size≥\$100K	13,767,800	2.1%	1.9%	4.0%	2.1%***
Trade size<\$100K	13,767,800	2.3%	2.3%	2.3%	0.0%
IG rated	11,100,026	3.8%	3.6%	5.5%	1.9%*
HY rated	2,667,774	5.0%	4.9%	8.9%	3.9%*

Multivariate analysis: Our multivariate specification is a panel regression with bond, α_j, and day, α_t, fixed effects:

$$y_{jt} = \alpha_j + \alpha_t + \beta_1 \times \left\{ \begin{array}{c} \text{HasQuote}_{jt} \\ \text{LogNoQuotes}_{jt} \end{array} \right\} + \beta_2 \times y_{jt-1} + \epsilon_{jt}. \tag{6}$$

The dependent variable, y_{jt}, is either the number of trades in bond j on day t, NoTrades_{jt}, natural log-transformed, LogNoTrades_{jt}, the number of trades in bond j on day t by CliQ dealers, NoTradesCliQ_{jt}, also natural log-transformed, or the market/trade share of CliQ dealers in bond j on day t defined as

$$\text{CliQ Trade Share}_{jt} = \frac{\text{NoTradesCliQ}_{jt}}{\text{NoTrades}_{jt}}. \tag{7}$$

The explanatory variable of interest is the indicator HasQuote_{jt} defined in the previous paragraph. Alternatively, we use LogNoQuotes_{jt} to capture the quoting intensity, which is the natural logarithm of the number of quotes plus one. Variation explained by bond characteristics and fixed income market conditions are controlled for by the bond fixed effects α_j and day fixed effects α_t. To account for the possibility of persistence in trading, we use lagged dependent variable, y_{jt-1}, as an additional explanatory variable. Standard errors are robust to clustering at the bond and day levels.

Table 3 summarizes the results from specification (6) for all trades (Panel A), for trades by CliQ dealers (Panel B), and for the share of trades of CliQ dealers as a fraction of the total number of trades (Panel C). Panels A and B report results from specification (6) for $\text{HasQuote}_{jt}/\text{LogNoQuotes}_{jt}$. without (Column 1/2) and with (Column 3/4) $\text{LogNoTrades}_{jt-1}$. Panel C reports similar market

Table 3: Aggregate quoting activity and trading activity

The table documents the relationship between CliQ dealer quoting activity and trading activity by CliQ dealers and non-CliQ dealers. We split trades by CliQ dealers versus non-CliQ dealers and collapse all trades at the dealer-bond-day level. Estimates are obtained from panel regressions with dealer, bond, and day fixed effects. Standard errors are double clustered at the bond and day level. Significance levels are *** 1%, ** 5%, * 10%.

	(1)	(2)	(3)	(4)
Panel A: Total number of trades (log)				
HasQuote_{ijt}	0.235***		0.175***	
	(0.013)		(0.009)	
LogNoQuote_{ijt}		0.193***		0.145***
		(0.010)		(0.007)
y_{jt-1}			0.259***	0.255***
			(0.007)	(0.007)
fe	Bond, Date	Bond, Date	Bond, Date	Bond, Date
r2	0.617	0.619	0.642	0.644
N	1,406,564	1,406,564	1,396,930	1,396,930
Panel B: CliQ dealer number of trades (log)				
HasQuote_{ijt}	0.128***		0.100***	
	(0.006)		(0.005)	
LogNoQuote_{ijt}		0.121***		0.096***
		(0.005)		(0.004)
y_{jt-1}			0.229***	0.222***
			(0.006)	(0.005)
fe	Bond, Date	Bond, Date	Bond, Date	Bond, Date
r2	0.435	0.440	0.464	0.467
N	1,406,564	1,406,564	1,396,930	1,396,930
Panel C: Share of CliQ dealer trades (fraction)				
HasQuote_{ijt}	0.021***		0.017***	
	(0.001)		(0.001)	
LogNoQuote_{ijt}		0.021***		0.018***
		(0.001)		(0.001)
y_{jt-1}			0.102***	0.101***
			(0.002)	(0.002)
fe	Bond, Date	Bond, Date	Bond, Date	Bond, Date
r2	0.100	0.101	0.109	0.111
N	796,294	796,294	639,542	639,542

share results with HasTrade_{jt-1} instead of $\text{LogNoTrades}_{jt-1}$ to control for trade persistence.

Consistent with the univariate results from Panel A of Table 2, Panel A of Table 3 shows that quoting increases the number of trades. The regression coefficient on HasQuote_{jt} is 0.235/0.175 (Column 1/3), significant at 1% level, without/with y_{jt-1} included in specification (6). Economically this implies that having a quote in bond j on date t increases the number of trades in this bond by 23.5%/17.5% on that day. The regression coefficient on y_{jt-1} is 0.259, significant at 1% level, thus demonstrating that trades are persistent. Economically it implies that 10% increase in the yesterday's number of trades leads to 2.59% increase in today's number of trades. When

LogNoQuotes_{jt} is used as the explanatory variable instead of HasQuote_{jt}, its regression coefficient is 0.193/0.145 (Column 2/4), significant at 1% level, without/with y_{jt-1}. Economically this implies that going from one to two (median value) quotes, translates into a 19.3%/14.5% increase in the number of trades. The regression coefficient on y_{jt-1} is 0.255, significant at 1% level.

Panel B of Table 3 reports results from the same specifications in Panel A, but for the trading volume of CliQ dealers only. Consistent with quoting increasing the number of trades, the regression coefficient on HasQuote_{jt} implies that having a quote from a CliQ dealer in bond j on date t increases the number of trades in this bond by 12.8%/10.0% on that day. The regression coefficient on y_{jt-1} implies that a 10% increase in the yesterday's number of trades leads to 2.29% increase in today's number of trades, which is quite similar to the result from Panel A on all trades. When LogNoQuotes_{jt} is used as the explanatory variable instead of HasQuote_{jt}, the regression coefficient imply that doubling the number of CliQ quotes translates into a 12.1%/9.6% increase in the number of trades by CliQ dealers.

Without information on the quoting activity by the non-CliQ dealers, results from Panels A and B must be interpreted with care. Panel C of Table 3 investigates whether the share of trades by CliQ dealers increases when they quote. The regression coefficient on HasQuote_{jt} is 0.021/0.017 (Column 1/3), significant at 1% level, with/without y_{jt-1} included in specification (6). Economically these imply that having a quote from a CliQ dealer in bond j on date t increases the share of CliQ dealers' trades in this bond by 2.1%/1.7% on that day. This finding confirms that when CliQ dealers quote, their quotes attract trades. The coefficient on y_{jt-1} is 0.102 and it is significant at 1% level. Economically it implies that if a CliQ dealer trades in bond j yesterday, it increases today's share of trades by CliQ dealers in bond j by 10.2%. Results for LogNoQuotes_{jt} reported in Columns 2 and 4 are similar to those reported in Columns 1 and 3.

Overall, consistently across specifications, more active quoting by CliQ dealers is associated with higher total trading activity, more trading by CliQ dealers, and higher share of trades by CliQ dealers. The results are both economically and statistically significant. Next, we investigate whether similar finding are present at the individual dealer level within CliQ dealers whose quoting activity we observe.

3.2 Do quotes attract trades at the dealer level?

We now turn to the impact that quoting activity at the individual dealer level has on the extensive and intensive margins of trading activity.

Univariate analysis: To examine quoting and trading within the CliQ dealers, we estimate the probability of having a trade depending on quoting activity in the same bond on the same day by the same dealer using the balanced panel of 13,968,550 dealer-bond-day observations. Following the approach described in Section 3.1, we obtain the daily trade probability in the same bond on the same day by the same dealer conditional on having/not having a quote. As in the case of aggregate trading activity, we control for trade size by splitting the sample into small, <\$100K, and large, ≥\$100K, trades, and we control for risk by splitting the sample into investment grade and high yield bonds.

Panel B of Table 2 reports dealer-level results. The absolute magnitudes are smaller than those reported in Panel A for the dealer-aggregated data. Still, a trade is more likely to take place on days with quoting activity, 5.7%, than on days without quoting activity, 3.9%, although the difference, 1.8%, is significant only at 10% level. Large trades are more likely to take place on days with quoting activity, 4.0%, than on days without quoting activity, 1.9%, and the difference, 2.1%, is statistically significant at 1% level. The effect of having a quote is not statistically significant for small trades. Finally, both IG and HY bonds are more likely to be traded on days with quoting activity, 5.5%/8.9%, than on days without quoting activity, 3.6%/4.9%, but the difference, 1.9%/3.9%, is significant only at 10% level. The effect of having a quote on the trade probability is greater for HY than IG bonds. This is, perhaps, because HY bonds are harder to price and trade than IG bonds and even more so during stress times.

Overall, these results support the main idea that quoting facilitates trading, both at the aggregate and individual dealer level, although the statistical significance is weaker in Panel B than in Panel A. We use multivariate analysis to further understand the link between quoting and trading at the individual dealer level. For the rest of the paper, we focus on CliQ dealers. We are specifically interested in whether the provision of a dealer quote is related to the likelihood the quoting dealer subsequently increases her trading activity on both the extensive, trade probability, and the intensive, number of trades, margins.

Extensive margin of trading activity: We start by estimating a linear probability model for how the occurrence of trades depend on quote provision. The dependent variable of interest is the indicator HasTrade_{ijt}, and the explanatory variable of interest is the indicator HasQuote_{ijt}. Alternatively, we use LogNoQuotes_{ijt} as the explanatory variable to capture quoting intensity.[10] Our specifications are panel regressions with dealer fixed effects α_i, bond fixed effects α_j, and day fixed effects α_t:

$$\text{HasTrade}_{ijt} = \alpha_i + \alpha_j + \alpha_t + \beta_1 \times \left\{ \begin{array}{c} \text{HasQuote}_{ijt} \\ \text{LogNoQuotes}_{ijt} \end{array} \right\} + \beta_2 \times \text{HasTrade}_{ijt-1} + \epsilon_{ijt}, \qquad (8)$$

where the lagged trade indicator, HasTrade_{ijt-1}, accounts for persistence in trading. Standard errors are robust to clustering at the dealer, bond, and day levels.

Panel A of Table 4 illustrates how quoting activity affects the dealer's trading activity at the extensive margin. Columns 1 through 4 report results for four variants of specification (8) all of which share the same fixed effects, but use the indicator $\text{HasQuote}_{ijt}/\text{LogNoQuotes}_{ijt}$ alone in Columns 1 and 2 and with HasTrade_{ijt-1} in Column 3 and 4. The regression coefficient on

[10]The distribution of the number of quotes is highly right-skewed.

HasQuote_{ijt}, β_1, captures the increase in the trade probability due to quoting by the same dealer in the same bond.

Column 1 of Panel A shows the estimate of β_1 is 0.040, which is statistically significant at 1% level. This is more than twice as high as its univariate counterpart from Panel B of Table 2 which is 0.018. This is because unlike the change in the *unconditional* trade probability reported in Panel B of Table 2, β_1 captures the change in the trade probability *conditional* on the bond, day and dealer fixed effects. The estimate of β_1 in Column 3, with the lagged trade indicator included in specification (8), is 0.033 (statistically significant at 1% level), while the estimate of β_2 is 0.221 (statistically significant at 1% level). Economically, the latter coefficient implies that if a trade has taken place by dealer i in bond j yesterday, than the probability of the same dealer trading in the same bond today increases by 0.221.

When LogNoQuotes_{jt} is the explanatory variable instead of HasQuote_{jt}, its regression coefficient is 0.049/0.040 (Column 2/4), significant at 1% level. Economically these imply that doubling[11] the number of quotes by dealer i in bond j on day t translates into a 0.049/0.040 increase in the trade probability by the same dealer in the same bond on the same day. The regression coefficient on HasTrade_{ijt-1} in Column 4 is 0.220 and it is significant at 1% level, similar to in Column 3. In summary, bonds with quotes are more likely to be traded than bonds without quotes on the same day by the quoting dealer even after controlling for past trading. The magnitude of the effect is both economically and statistically significant.

Intensive margin of trading: We next examine the intensive trading margin through the relation between quoting and the number of trades by the quoting dealer. The dependent variable of interest is LogNoTrades_{ijt} which is defined as the natural logarithm of the number of trades by dealer i in bond j on day t plus one, given that the dealer trades. Our base specifications are panel regressions with dealer fixed effects α_i, bond fixed effects α_j, and day fixed effects α_t:

$$\text{LogNoTrades}_{ijt} = \alpha_i + \alpha_j + \alpha_t + \beta_1 \times \left\{ \begin{array}{c} \text{HasQuote}_{ijt} \\ \text{LogNoQuotes}_{ijt} \end{array} \right\} + \beta_2 \times \text{LogNoTrades}_{ijt-1} + \epsilon_{ijt}, \quad (9)$$

where we include $\text{LogNoTrades}_{ijt-1}$ to account for the persistence in trading. Standard errors are robust to clustering at the dealer, bond, and day levels.

Panel B of Table 4 has the same layout as Panel A and shows that quoting affects the dealer's trading activity at the intensive margin. Column 1 of Panel B shows the estimate of β_1 is 0.036 and it is statistically significant at 1% level. Economically, it implies that quoting by dealer i in bond j on day t increases dealer i's number of trades in the same bond on the same day by 3.6%. The estimate of β_1 in Column 3, with the lagged trade indicator included in specification (8), is 0.028, while the estimate of β_2 is 0.265, with both estimates being statistically significant at 1% level. Economically, the latter coefficient implies that 10% increase in the number of yesterday's

[11]Panel C of Table 1 shows the average number of quotes by dealer i in bond j on date t is 1.

Table 4: Impact of dealer's quoting activity on order flow

The table documents the determinants of dealer trades. In Panel A, the dependent variable equals one if dealer i trades bond j on day t, and zero otherwise. In Panel B, the dependent variable equals the natural logarithm of the number of trades plus one by dealer i in bond j on day t. Estimates are obtained from panel regressions with dealer fixed effects, bond fixed effects, and day fixed effects. Standard errors are triple clustered at the dealer, bond, and day level. Significance levels are *** 1%, ** 5%, * 10%.

Panel A: Trading activity, extensive margin				
	(1)	(2)	(3)	(4)
	HasTrade_{ijt}	HasTrade_{ijt}	HasTrade_{ijt}	HasTrade_{ijt}
HasQuote_{ijt}	0.040***		0.033***	
	(0.008)		(0.006)	
LogNoQuote_{ijt}		0.049***		0.040***
		(0.007)		(0.006)
HasTrade_{ijt-1}			0.221***	0.220***
			(0.011)	(0.011)
fe	Triple	Triple	Triple	Triple
r2	0.055	0.057	0.102	0.103
N	13,767,800	13,767,800	13,767,800	13,767,800

Panel B: Trading activity, intensive margin				
	(1)	(2)	(3)	(4)
	LogNoTrades_{ijt}	LogNoTrades_{ijt}	LogNoTrades_{ijt}	LogNoTrades_{ijt}
HasQuote_{ijt}	0.036***		0.028***	
	(0.008)		(0.006)	
LogNoQuote_{ijt}		0.045***		0.035***
		(0.007)		(0.005)
$\text{LogNoTrades}_{ijt-1}$			0.265***	0.264***
			(0.015)	(0.015)
fe	Triple	Triple	Triple	Triple
r2	0.055	0.057	0.121	0.122
N	13,767,800	13,767,800	13,673,500	13,673,500

trades by dealer i in bond j translates into 2.65% increase in today's trades by the same dealer in the same bond.

When LogNoQuotes_{jt} is used as the explanatory variable instead of HasQuote_{jt}, its regression coefficient is 0.045/0.035 (Column 2/4), statistically significant at the 1% level. Economically it implies that doubling the number of quotes by dealer i in bond j on day t translates into a 4.5%/3.5% increase in the number of trades by the same dealer in the same bond on the same day. The regression coefficient on $\text{LogNoTrades}_{jt-1}$ in Column 4 is 0.264 and it is statistically significant at 1% level, making it quite similar to the one from Column 3.

In summary, quoting by a dealer increase trading at both the extensive (trade probability) and intensive (number of trades) margins at the dealer-bond-day level. The magnitudes of both effects are economically and statistically significant. Next, we study how the aggressiveness of dealer quotes affects trading. For dealers to have an incentive to compete on quotes, more aggressive quotes should attract more order flow.

4 Quote quality and order flow

Given that dealer quotes attract trades, we next study whether better quotes attract more order flow. We do this by examining the relative aggressiveness of dealers' quotes within a bond, which we refer to as quote quality, and relate it to dealers' order flow.

4.1 Do more aggressive quotes attract more order flow?

To analyze if higher quality quotes attract order flow for dealer i in bond j on date t, we estimate the following specifications:

$$\left\{ \begin{array}{c} \text{HasTrade}_{ijt} \\ \text{LogNoTrades}_{ijt} \end{array} \right\} = \alpha_i + \alpha_j + \alpha_t + \beta_1 \times \text{QuoteQuality}_{ijt} + \beta_2 \times \left\{ \begin{array}{c} \text{HasQuote}_{ijt} \\ \text{LogNoQuotes}_{ijt} \end{array} \right\} + \\ + \gamma' X_{ijt} + \epsilon_{ijt}, \quad (10)$$

with standard errors robust to clustering at the dealer, bond, and day levels. We estimate specification (10) on the whole sample and on sub-samples of large (trade size$\geq$\$100K) and small (trade size$<$\$100K) trades. Controls, X_{ijt}, include the number of dealers quoting bond j on day t, $\text{NoFirmsQuoting}_{jt}$, as well as lagged explanatory variables HasTrade_{ijt-1} and $\text{LogNoTrades}_{ijt-1}$ to control for the persistence in trading.

Table 5 reports the results for the extensive margin of trading, HasTrade_{ijt}, in Columns 1 to 3, and for the intensive margin of trading, LogNoTrades_{ijt}, in Columns 4 to 6, using the distance to average quote as a measure of quote quality.[12] Columns 1 and 4 reports results for all trades, Columns 2 and 5 reports results for large trades, and Columns 3 and 6 reports results for small trades.

Extensive margin of trading: We start with the effect of the quote quality on the extensive margin of trading. Column 1 of Table 5 shows that the regression coefficient on $\text{QuoteQuality}_{ijt}$, β_1, is 0.025 and it is statistically significant at 5% level. Economically, it implies that if dealer i increases its quote quality in bond j on day t by one standard deviation, 22bps from Panel A of Table 1, then the probability of trading by that dealer in that bond on that day increases by 0.0055. The dealer-level probability of trading conditional on quoting is 0.057 (5.7%) from Panel B of Table 2, implying that one standard deviation improvement in quote quality increases trade probability at the dealer-bond-day level by 9.65% (0.0055/0.057=0.0965).

[12] Table C.2 reports our results for distance to the best quote as an alternative measure of quote quality. The results are quite similar to results reported in Table 5.

Table 5: Importance of quote quality to attract order flow

The table documents the importance of quote quality to attract order flow. The dependent variable captures the trading activity by dealer i in bond j on day t by HasTrade_{ijt} or LogNoTrades_{ijt}. Quote quality is the distance to the average quote. Estimates are obtained from panel regressions with dealer fixed effects, bond fixed effects, and day fixed effects. Standard errors are triple clustered at the dealer, bond, and day level. Significance levels are *** 1%, ** 5%, * 10%.

	Extensive margin: HasTrade_{ijt}			Intensive margin: LogNoTrades_{ijt}		
	(1)	(2)	(3)	(4)	(5)	(6)
	All trades	Trade size ≥$100K	Trade size <$100K	All trades	Trade size ≥$100K	Trade size <$100K
$\text{QuoteQuality}_{ijt}$	0.025**	0.026***	0.001	0.022**	0.024***	-0.000
	(0.010)	(0.009)	(0.005)	(0.008)	(0.007)	(0.004)
HasQuote_{ijt}	0.030***	0.025***	0.010***			
	(0.007)	(0.006)	(0.003)			
LogNoQuote_{ijt}				0.033***	0.028***	0.009***
				(0.005)	(0.004)	(0.003)
$\text{NoFirmsQuoting}_{jt}$	0.004***	0.003***	0.001***	0.003***	0.002***	0.001***
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
y_{ijt-1}	0.221***	0.178***	0.196***	0.264***	0.206***	0.243***
	(0.011)	(0.007)	(0.014)	(0.015)	(0.008)	(0.020)
fe	Triple	Triple	Triple	Triple	Triple	Triple
r2	0.102	0.063	0.089	0.123	0.075	0.108
N	13,673,500	13,673,500	13,673,500	13,673,500	13,673,500	13,673,500

The coefficient on HasQuote_{ijt}, β_2, is 0.030, which is lower than the coefficient from Column 1 of Panel A of Table 4, which is 0.040. This suggests that the quote quality subsumes some of the information contained in the the quote indicator relevant to the probability of trading by the same dealer i in the same bond j on the same day t. Trade probability in bond j increases by 0.003 (0.3%), statistically significant at 1% level, on days when the number of dealers quoting bond j increases from one to two (the median value). The regression coefficient on HasTrade_{jt-1} is 0.221 and it is identical to its counterpart from Column 3 of Panel A of Table 4.

Columns 2 and 3 of Table 5 show that the positive relationship between the quote quality and trade probability at the dealer-bond-day level is due to large trades (trade size ≥ $100K, Column 2). While regression coefficients on $\text{QuoteQuality}_{ijt}$ are both positive in Columns 2 and 3, only the former is economically and statistically significant. For large trades, the estimate of 0.026 means economically that if dealer i increases the quote quality in bond j on day t by one standard deviation, the probability of executing a large trade increases by 0.57%. The dealer-level probability of a large trade conditional on quoting is 0.04 (4.0%) from Panel B of Table 2, implying that one standard deviation improvement in quote quality increases the probability of a large trade at the dealer-bond-day level by 14.3% (0.0057/0.04=0.143).

The regression coefficient on HasQuote_{ijt} is also bigger for large trades, 0.025 (Column 2), than for small trades, 0.010 (column 3), although both coefficients are statistically significant at 1%

level. The same relation applies to the regression coefficient on $\text{NoFirmsQuoting}_{jt}$, 0.003 vs. 0.001. However, the regression coefficient on the lagged trade dummy in the same bond by the same dealer is bigger for small trades, 0.196 (Column 3), than it is for large trades, 0.178 (Column 2). Overall, the relation between the extensive margin of trading and quote quality is positive and both economically and statistically significant. This results can be attributed to large trades as the quote quality does not affect the probability of small trades.

Intensive margin of trading: We now investigate the relation between the quote quality and the intensive margin of trading. Column 4 of Table 5 shows that the regression coefficient on $\text{QuoteQuality}_{ijt}$, $\beta_1 = 0.022$, is positive and statistically significant. Economically, it implies that if dealer i increases the quote quality in bond j on day t by one standard deviation (22bps), the number of trades by that dealer in that bond on that day increases by 0.48%. This relation is also due to large trades (Column 5) for whom $\beta_1 = 0.024$ is positive and statistically significant. In contrast, β_1 for small trades (Column 6) is equal -0.000 and is not statistically significant. For large trades, the estimate of 0.024 means that if dealer i increases the quote quality in bond j on day t by one standard deviation (22bps) then the number of trades by the same dealer in the same bond on the same day increases by 0.53%. Thus, quote quality is important mostly for large trades.

The regression coefficient on LogNoQuotes_{ijt}, β_2, is 0.033, which is similar its counterpart from Column 4 of Panel B of Table 4. It means that the information in $\text{QuoteQuality}_{ijt}$ relevant to the number of trades by the same dealer i in the same bond j on the same day t is orthogonal to the information in LogNoQuotes_{ijt} on the same day. Quote quantity is also more important for large trades whose β_2 is 0.028, which is much bigger than β_2 for small trades, 0.009. Both regression coefficients are statistically significant at 1% level.

The coefficient on number of dealers quoting bond j is positive and statistically significant at 1% level, with most of the effect coming from large trades for whom the regression coefficient is 0.002 (Column 5), while the regression coefficient for small trades is 0.001 (Column 6). Both coefficients are significant at 1% level. The regression coefficient on HasTrade_{jt-1} is 0.264 and it is statistically significant at 1% level, similar to Table 4, Panel B, with larger effects for small trades, 0.243 (Column 6), than large trades, 0.206 (Column 5). Overall, the relation between the intensive margin of trading and quote quality is positive, economically and statistically significant, and, just like in the case of the extensive margin, it is due to large trades as the quote quality does not affect the number of small trades.

In summary, our findings suggest that dealers use quotes to compete for the order flow and to advertise their willingness to trade. Better quotes increase trading at the extensive margin (probability of trading) and the intensive margin (number of trades) at the dealer-bond-day level. However, the effect of both quote *quantity* and *quality* on the order flow is primarily in large trades. For small trades, having a quote and past trading in the same bond with the same dealer increases the trade probability and number of trades, but quote quality does not.

4.2 Determinants of order flow sensitivity to quotes

We next examine whether the impact of quoting activity on trading intensity depends on the quote quality, bond type and market-wide uncertainty. We do so by interacting the provision of quotes with the dealer's quote quality, bond type, and market conditions. To simplify notation define

$$Z_{ijt} \equiv \{\text{QuoteQuality}_{ijt}, \text{Bond type}_{jt}, \text{Market condition}_t\}.$$

As above, we study both the extensive, HasTrade_{ijt}, and intensive, LogNoTrades_{ijt}, margins of trading when estimating the following balanced panel specifications:

$$\left\{ \begin{array}{c} \text{HasTrade}_{ijt} \\ \text{LogNoTrades}_{ijt} \end{array} \right\} = \alpha_i + \alpha_j + \alpha_t + \beta_1 \times \text{LogNoQuotes}_{ijt} \times Z_{ijt} + \beta_2 \times \text{LogNoQuotes}_{ijt} + \\ + \beta_3 \times Z_{ijt} + \beta_4 \times \left\{ \begin{array}{c} \text{HasTrade}_{ijt-1} \\ \text{LogNoTrades}_{ijt-1} \end{array} \right\} + \gamma' X_{ijt} + \epsilon_{ijt}, \quad (11)$$

with standard errors robust to clustering at the dealer, bond, and day levels. We estimate specifications (11) on the the whole sample and on sub-samples of large (trade size≥\$100K) and small (trade size<\$100K) trades. To proxy for credit risk we use the investment grade indicator, IG rating_{jt}, equal to one if bond j has investment grade rating on day t and zero otherwise. VIX_t is a proxy for market stress conditions on day t. Controls X_{ijt} are the same as in specification (10).

Table 6 presents the estimation results. Focusing on the coefficients for the interaction terms, we find that higher quote quality is associated with a higher sensitivity of order flow (both extensive margin and intensive margin) to quote activity. While this true for trades across all sizes, the magnitude of the coefficients suggest that this effect is stronger for institution-sized trades.

Market uncertainty or uncertainty about bond values appears to affect order flow sensitivity to quote as well. We find that β_1 is negative when LogNoQuotes is interacted with a dummy for investment grade bonds, and positive when LogNoQuotes is interacted with VIX, suggesting that order flow responds to quote activity more when VIX is high and for speculative grade bonds. Since quoting activities tend to decline during market stress, our results suggest that the remaining quotes in the market attract more order flow on average. Next, we investigate whether dealer quote competition affects the client execution quality.

5 Do quotes improve client execution quality?

The previous section shows that quote competition matters in that the presence of a quote, the number of quotes, and the quality of quotes attract order flow. In this section, we explore whether dealer quotes improve client execution quality. Better quoted prices leading to better transaction prices explain why quotes attract order flow and why customers benefit from quote competition.

Table 6: Determinants of order flow sensitivity to quotes

The table documents the determinants of order flow sensitivity to quotes. The dependent variable captures the trading activity by dealer i in bond j on day t by HasTrade_{ijt} or LogNoTrades_{ijt}. Estimates are obtained from panel regressions with dealer fixed effects, bond fixed effects, and day fixed effects as specified in the respective column. Standard errors are triple clustered at the dealer, bond, and day level. Significance levels are *** 1%, ** 5%, * 10%.

	Extensive margin: HasTrade_{ijt}			Intensive margin: LogNoTrades_{ijt}		
	(1)	(2)	(3)	(4)	(5)	(6)
	All trades	Trade size ≥$100K	Trade size <$100K	All trades	Trade size ≥$100K	Trade size <$100K
$\text{LogNoQuotes}_{ijt} \times \text{QuoteQuality}_{ijt}$	0.157***	0.181***	0.158***	0.160***	0.155***	0.182***
	(0.024)	(0.029)	(0.025)	(0.025)	(0.024)	(0.029)
$\text{LogNoQuotes}_{ijt} \times \text{IG Rating}_{jt}$	-0.029**	-0.035**	-0.027**	-0.031**	-0.025**	-0.035**
	(0.012)	(0.014)	(0.012)	(0.012)	(0.011)	(0.014)
$\text{LogNoQuotes}_{ijt} \times \text{VIX}_t$	0.049***	0.060***	0.047***	0.049***	0.048***	0.060***
	(0.013)	(0.015)	(0.014)	(0.014)	(0.013)	(0.015)
LogNoQuotes_{ijt}	0.055***	0.064***	0.054***	0.058***	0.052***	0.064***
	(0.013)	(0.016)	(0.013)	(0.014)	(0.012)	(0.016)
$\text{QuoteQuality}_{ijt}$	-0.105***	-0.121***	-0.106***	-0.107***	-0.103***	-0.122***
	(0.019)	(0.023)	(0.020)	(0.020)	(0.019)	(0.023)
$\text{NoFirmsQuoting}_{jt}$	0.003***	0.004***	0.003***	0.003***	0.003***	0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
y_{ijt-1}	0.219***	0.229***	0.257***	0.219***	0.246***	0.257***
	(0.011)	(0.015)	(0.009)	(0.008)	(0.012)	(0.019)
fe	Triple	Triple	Triple	Triple	Triple	Triple
r2	0.104	0.087	0.085	0.083	0.110	0.090
N	13,673,500	13,673,500	13,673,500	13,673,500	13,673,500	13,673,500

5.1 Client execution quality

Client execution quality is defined in expression (4), and is essentially the negative of trading costs, so higher execution quality indicates lower transaction costs. While two alternate benchmarks are used to construct $\text{ClientExecutionQuality}_{ijt}$, for ease of exposition in this section we report results only for the benchmark based on the BAML end-of-day quote on the same bond on the day prior to the transaction.[13] Panel B of Table 1 provides basic descriptive statistics for $\text{ClientExecutionQuality}_{ijt}$ and Panel A of Table 7 supplements these with additional useful descriptive statistics for client execution quality split by trade size and credit rating across rows.

The average/median execution quality is -37bps/-15bps. The standard deviation of 1.75% implies a large dispersion in execution quality. Smaller trades receive on average much lower execution quality than large trades, -54bps versus -24bps. The execution quality for IG bonds is on average slightly better than that for speculative grade bonds, -36bps versus -40bps. Overall, there exists significant heterogeneity in the execution quality across different trade sizes and bond credit ratings. We proceed to use multivariate analysis to link the execution quality to quote quality.

[13] Table C.3 reports our results for the price on the last interdealer trade prior to the transaction an alternative benchmark. The results are quite similar to results reported in Table 7.

Table 7: Client execution quality and dealer quotes

The table documents the impact on client execution quality of dealer quotes and quote quality. Estimates are obtained from panel regressions with dealer fixed effects, bond fixed effects, and day fixed effects interacted with a buy-sell indicator. Standard errors are triple clustered at the dealer, bond, and day level. Significance levels are *** 1%, ** 5%, * 10%.

Panel A: Descriptive statistics on $\text{ClientExecutionQuality}_{ijt}$

	N	Mean	SD	5%	25%	50%	75%	95%
$\text{ClientExecutionQuality}_{ijt}$	417,512	-0.37	1.75	-2.87	-0.64	-0.15	0.13	1.43
Trade size≥$100K	233,106	-0.24	1.79	-2.72	-0.53	-0.12	0.19	1.81
Trade size<$100K	184,406	-0.54	1.67	-3.02	-0.81	-0.19	0.07	0.85
IG rated	303,876	-0.36	1.69	-2.71	-0.55	-0.13	0.12	1.16
HY rated	113,636	-0.40	1.88	-3.18	-0.88	-0.22	0.16	2.09

Panel B: Impact of dealer's quote quality on $\text{ClientExecutionQuality}_{ijt}$

	(1)	(2)	(3)
	All trades	Trade size≥$100K	Trade size<$100K
$\text{QuoteQuality}_{ijt}$	0.450***	0.510***	0.182
	(0.074)	(0.088)	(0.129)
$\text{BenchmarkUpdate}_{jt}$	0.632***	0.655***	0.505***
	(0.050)	(0.053)	(0.047)
HasQuote_{ijt}	0.094***	0.041	0.050**
	(0.029)	(0.029)	(0.024)
AnyQuote_{jt}	0.206***	0.250***	0.124**
	(0.052)	(0.054)	(0.055)
fe	Quad	Quad	Quad
r2	0.318	0.316	0.381
N	417,292	232,804	183,679

Panel C: Impact of market conditions on $\text{ClientExecutionQuality}_{ijt}$

	(1)	(2)	(3)
	All trades	Trade size≥$100K	Trade size<$100K
VIX_t	-1.363***	-0.920***	-2.055***
	(0.188)	(0.182)	(0.256)
$\text{QuoteQuality}_{ijt}$	0.059	0.146	0.147
	(0.184)	(0.168)	(0.250)
$\text{QuoteQuality}_{ijt} \times \text{VIX}_t$	1.458**	1.489**	-0.069
	(0.629)	(0.674)	(0.872)
$\text{BenchmarkUpdate}_{jt}$	0.790***	0.836***	0.616***
	(0.060)	(0.062)	(0.053)
HasQuote_{ijt}	0.079**	-0.005	0.055
	(0.034)	(0.011)	(0.038)
AnyQuote_{jt}	0.290***	0.350***	0.180***
	(0.048)	(0.050)	(0.050)
$\text{DealerSellTrade}_{ijt}$	0.004	0.021	-0.035
	(0.130)	(0.147)	(0.108)
fe	Double	Double	Double
r2	0.121	0.090	0.223
N	417,292	232,804	183,679

Relations (3)–(5) for $\text{QuoteQuality}_{ijt}$, $\text{ClientExecutionQuality}_{ijt}$, and $\text{PriceImprovement}_{ijt}$, respectively, allow for a convenient decomposition of the client's execution quality by dealer i in bond j on day t into price improvement and quote quality by the same dealer in the same bond on the same day, and the aggregate quote update over the benchmark price (yesterday's BAML quote) for the same bond on the same day:

$$\text{ClientExecutionQuality}_{ijt} \equiv \text{PriceImprovement}_{ijt} + \text{QuoteQuality}_{ijt} + \text{BenchmarkUpdate}_{jt}, \quad (12)$$

where the aggregate quote update over the benchmark price, $\text{BenchmarkUpdate}_{jt}$, is defined as:

$$\text{BenchmarkUpdate}_{jt} = \text{BenchmarkQuote}_{jt} - \text{BenchmarkPrice}_{jt}. \quad (13)$$

Identity (12) lends itself to estimating the degree to which dealer quotes matter for client execution quality. Quotes matter if they are firm or at least impact the bilateral negotiations between dealer and client. We use the following specification to estimate how quote quality impacts execution quality:

$$\begin{aligned}\text{ClientExecutionQuality}_{ijt} = \alpha_i + \alpha_j + \alpha_t + \delta \times \text{QuoteQuality}_{ijt} + \beta \times \text{BenchmarkUpdate}_{ijt} + \\ + \gamma_1 \times \text{HasQuote}_{ijt} + \gamma_2 \times \text{AnyQuote}_{jt} + \gamma_3 \times \alpha_t \times \text{DealerSellTrade}_{ijt} + \epsilon_{ijt}. \quad (14)\end{aligned}$$

$\text{QuoteQuality}_{ijt}$ can be non-zero only when the Benchmark quote_{jt} is defined. To control for variation in quoting activity, we include indicators for quoting activity by dealer i, HasQuote_{ijt}, and by *any* dealer, AnyQuote_{jt}, in bond j on date t. AnyQuote_{jt} equals one whenever one or more dealers are quoting the bond, and zero otherwise. The coefficient on AnyQuote_{jt} measures the difference in average execution quality between bond-days with and without quotes with a positive coefficient implying that execution quality is better on bond-days when dealers provide quotes. To control for possible asymmetries due to the trade direction during stress periods, we include day fixed effects interacted with a buy-sell indicator, $\text{DealerSellTrade}_{ijt}$, that equals one if dealer i sells bond j on day t and zero otherwise.

Panel B of Table 7 documents results from specification (14) on how dealer's quote quality impacts client execution quality. Results are reported for the pooled sample (Column 1), large trades (Column 2), and small trades (Column 3).

In specification (14), the coefficient δ captures the degree to which a dealer's quotes are firm. If $\delta = 1$, better quality quotes affect client execution quality one-to-one, or, in other words, all quote quality is passed through to the client via the execution quality. The hypothesis $H_0 : \delta = 1$ thus provides a test for whether quotes are firm.[14]. At the other extreme, if $\delta = 0$ quote quality does not affect client execution quality at all. In this case, quotes are meaningless. The hypothesis

[14]Even with firm quotes, a delay between quote dissemination and trade time can cause delta to be less than 1, reflecting changes in market conditions after the quote is made available.

$H_0 : \delta = 0$ thus provides a test for whether quotes affect client execution quality. Overall, the range of δ estimates can be summarized as follows:

$$\delta = \begin{cases} 0 & \text{Quotes are meaningless,} \\ (0,1) & \text{Quotes are meaningful, but not firm,} \\ 1 & \text{Quotes are firm.} \end{cases} \tag{15}$$

For all trades pooled (Column 1), the coefficient δ on quote quality is 0.450, which is significantly different from zero. It implies about 45% pass-through of the quote quality to prices received by clients. Hence, quotes matter for the clients' prices. When we split between large (Column 2) and small (Column 3) trades, we find that almost all of the effect derives from large trades. The coefficient δ on quote quality for large trades is 0.510 thus implying 51% quote quality pass-through for them. The coefficient δ is 0.182 for small trades and it is neither economically nor statistically significant. To the extent that a small trade size proxies for retail investors, this result suggests that retail investors do not benefit from quote competition because they do not have access to dealer quotes. By contrast, institutional investors benefit from quote competition.

The coefficient on HasQuote_{ijt} equals 0.094 and is statistically significant at 1% level for all trades pooled (Column 1). Economically it means that the average execution quality improves by 9.4bps between bond-days when dealer i does and does not quote bond j. However, when we split between large (Column 2) and small (Column 3) trades, we find that coefficients on HasQuote_{ijt} for large, 0.041, and small, 0.050, trades are not economically significant and only the former is statistically significant at 5% level. The coefficient on AnyQuote_{jt} is larger than the coefficient on HasQuote_{ijt} for all trades (Column 1), 0.206 vs. 0.094, large trades (Column 2), 0.250 vs. 0.041, and small trades (Column 3), 0.124 vs. 0.050. It is statistically significant at the 5% level for small trades and at the 1% level for all and large trades. Economically, the average execution quality for large trades in bond j improves by about 25bps between bond-days with and without quotes in bond j. These findings further confirm that quoting is important primarily for large trades.

Finally, we investigate how CliQ dealers quotes affect execution quality under different market conditions. To do this we supplement specification (14) with VIX as a proxy for market stress and interact it with quote quality, to yield the following specification:

$$\begin{aligned} \text{ClientExecutionQuality}_{ijt} &= \alpha_i + \alpha_j + \delta_1 \times \text{VIX}_t + \delta_2 \times \text{QuoteQuality}_{ijt} + \\ &+ \delta_3 \times \text{QuoteQuality}_{ijt} \times \text{VIX}_t + \beta \times \text{BenchmarkUpdate}_{ijt} + \gamma' X_{ijt} + \epsilon_{ijt}, \end{aligned} \tag{16}$$

where controls, X_{ijt}, include the quote indicators HasQuote_{ijt} and AnyQuote_{jt}. Because VIX is replacing day fixed effects relative to specification (14), we drop day fixed effects interacted with a buy-sell indicator from X_{ijt} and, instead, include in it the indicator for dealer sell trades, $\text{DealerSellTrade}_{ijt}$.

Panel C of Table 7 reports these results. Several results stand out. First, client execution quality is lower during market stress periods for all trades, as well as large and small trades. One standard deviation increase in VIX (17.97%) decreases the execution quality by 24bps/17bps/37bps for all/large/small trades. Second, quote quality by itself is not statistically significant for all trades as well as large and small trades. Third, client execution quality is more sensitive to quote quality when VIX is higher. Interestingly, this effect only exist for institution-sized trades, consistent with the idea that retail investors are likely not exposed to dealer quotes and do not benefit from quote competition.

Finally, we briefly discuss the remaining regression coefficients. The coefficient on the quote dummy, HasQuote_{ijt}, is no longer statistically significant for large and small trades. It is 0.079 for all trades pooled and is statistically significant at the 5% level. However, the coefficient on AnyQuote_{jt} is much larger in this specification with VIX than in specification (14) without VIX for all, 0.290 vs. 0.206, large, 0.350 vs. 0.250, and small, 0.180 vs. 0.124, trades. All coefficients are statistically significant at the 1% level. Economically it means that the average execution quality for large/small trades in bond j improves by 35bps/18bps between bond-days with and without quotes in bond j. These findings highlight that having a quote from any dealer may be more important than to have a quote from the dealer with whom the trade is consummated. Finally, the regression coefficient on the dealer sell-trade dummy is neither statistically nor economically significant for any trade category.

In summary, quotes are meaningful but not completely firm. Competition between dealers on quotes strongly affects trade outcomes via the aggressiveness of quotes (quote quality) by the transacting dealer as 45% to 51% of a dealer's quote quality is passed through to the transaction price. Quotes also appear to help clients in negotiating transaction prices with other dealers. To further understand the firmness of dealer quotes, we next investigate the amount of price improvement over quotes.

5.2 Price improvement from quote competition

The previous section documents that quoted bid-ask spreads are not fully firm and quoted prices differ from traded prices. We next analyze if dealers trade at better or worse prices than their quotes and whether bond, market, or trade characteristics determine price improvement.

For dealer i and bond j on date t, we define price improvement over the quoted bid-ask prices that the dealer provides to the client on the transaction given by expression (5). We use the last quote provided by the dealer as the relevant dealer quote. Trades that are not preceded by a quote from the same dealer in the same bond on the same day are eliminated as we cannot compute price improvement. By identity (12) price improvement is one of several components of the client execution quality studied in the previous section.

Table 8 reports price improvement overall, by trade size, by bond credit rating, by quote quality, and by market conditions (VIX). The sample average/median price improvement across all trades

Table 8: Price improvement over quote

The table documents the price improvement over dealer's quote defined in (5) at the dealer-bond-day level. We use the last quote provided by the dealer as the relevant dealer quote. Trades that are not preceded by a quote from the same dealer in the same bond on the same day are eliminated since we cannot compute price improvement.

Panel A: Descriptive statistics on PriceImprovement$_{ijt}$								
	Mean	SD	5%	25%	50%	75%	95%	N
PriceImprovement$_{ijt}$ (\$)	0.07	0.75	-0.75	-0.04	0.03	0.19	0.89	40,844
Trade size≥\$100K	0.12	0.71	-0.45	-0.02	0.04	0.21	0.95	31,567
Trade size<\$100K	-0.11	0.83	-1.63	-0.12	0.00	0.12	0.74	9,277
IG rated	0.07	0.74	-0.72	-0.04	0.03	0.18	0.88	37,516
HY rated	0.08	0.75	-1.09	-0.03	0.05	0.25	1.03	3,328
Panel B: PriceImprovement$_{ijt}$, split by QuoteQuality$_{ijt}$								
Quartile of QuoteQuality$_{ijt}$	Mean	SD	5%	25%	50%	75%	95%	N
Low	0.18	0.87	-0.81	-0.02	0.09	0.34	1.27	8,230
2	0.04	0.60	-0.44	-0.03	0.02	0.11	0.52	6,277
3	0.05	0.36	-0.20	-0.02	0.02	0.10	0.43	8,012
High	-0.01	0.83	-1.29	-0.12	0.02	0.21	0.86	8,654
Panel C: PriceImprovement$_{ijt}$, split by VIX$_t$								
Quartile of VIX$_t$	Mean	SD	5%	25%	50%	75%	95%	N
Low	0.02	0.37	-0.45	-0.03	0.02	0.12	0.50	10,394
2	0.04	0.38	-0.38	-0.02	0.03	0.14	0.54	10,111
3	0.06	0.71	-0.67	-0.04	0.03	0.19	0.76	10,332
High	0.16	1.20	-1.41	-0.09	0.06	0.40	1.91	10,007

reported in Panel A is 7bps/3bps with a standard deviation of 75bps. The price improvement can be as high/low as 89bps/-75bps for some trades. Most of the price improvement occurs for large trades. The average/median price improvement for large trades is 12bps/4bps with the standard deviation of 71bps, while for small trades it is -11bps/0bps with the standard deviation of 83bps. This is not surprising since retail investors, who are mostly responsible for small trades, do not receive CliQ quotes. In contrast, institutions are more likely to receive CliQ quotes and thus directly benefit from quote competition by getting improved prices. IG and HY bonds have similar price improvement. The average/median price improvement for IG bonds is 7bps/3bps with a standard deviation of 74bps, while for HY bonds it is 8bps/5bps with a standard deviation of 75bps.

Panel B of Table 8 splits PriceImprovement$_{ijt}$ into quartiles by QuoteQuality$_{ijt}$.[15] The univariate sort on the transacting dealer's quote quality shows that more aggressive quotes are associated with less improvement of the transaction price over the quoted price. This holds true at the mean, median, and right tail. Dealers thus improve their transaction prices when they have poor quotes (18bps/9bps at the mean/median for quartile 1). At the other extreme, dealers with very attractive quotes provide little to no price improvement (-1bps/2bps at the mean/median for quartile 4).

Panel C of Table 8 splits PriceImprovement$_{ijt}$ into quartiles by VIX$_t$. The univariate sort on

[15] The unequal number of observations in each quartile is due to overdispersion at zero.

periods of market calm versus stress shows that more stressful periods (with fewer quotes, fewer dealers quoting, and worse quotes) are associated with more improvement of the transaction price over the quoted price. This holds true at the mean, median, and right tail (16bps/6bps at the mean/median for quartile 4 as compared to 2bps/2bps for quartile 1).

Overall, these results are consistent with our findings from the previous section. Dealers with bad quotes improve transaction prices over their quotes more than dealers with good quotes. The sample average price improvement of 7bps is economically significant compared to the average execution quality of -37bps. Price improvement is particularly high for large trades and during periods of market stress when VIX is high.

6 Intraday lead-lag relation between quotes and trades

Previous sections establish a strong relation between trades and quotes at the bond-day and dealer-bond-day levels. These analysis are performed daily. A natural concern with this level of aggregation is that unobserved factors could affect both trading and quoting in a bond on a certain day, thus limiting the ability to establish a casual link. We first show that most of the quotes were sent out before trades happen. Figure 2 shows that the quoting activity peaks at 8AM and then gradually declines through the rest of the day until 6pm when it almost stops. Therefore, a large proportion of quotes were sent out before noon. The arrival times of trades are typically later, with trading activity low at 8AM and then increases between 8AM and 11AM then plateaus between 11AM and 3PM, spikes at 3PM and then winds down by 5PM. A larger share of trades happen after noon. Panel A of Table 9 provides additional statistics for AM (before noon) and PM (after noon) quotes and trades. The average AM/PM number of quotes is 0.127/0.052. The average number of trades is 0.024/0.042. Overall these results are indicative of the lead-lag intraday relation between quotes and trades, which we explore further in this section.

Our specification is a VAR for the extensive trading, HasTrade_{ijt}, and quoting, HasQuote_{ijt}, margins with dealer, bond, and day fixed effects

$$\begin{pmatrix} \text{HasTrade}_{ijt}^{PM} \\ \text{HasQuote}_{ijt}^{PM} \end{pmatrix} = \alpha_i + \alpha_j + \alpha_t + \begin{pmatrix} \beta_{11} & \beta_{12} \\ \beta_{21} & \beta_{22} \end{pmatrix} \begin{pmatrix} \text{HasTrade}_{ijt}^{AM} \\ \text{HasQuote}_{ijt}^{AM} \end{pmatrix} + \begin{pmatrix} \epsilon_{ijt}^{1} \\ \epsilon_{ijt}^{2} \end{pmatrix}, \quad (17)$$

and we also estimate the same VAR specification for the intensive quoting, LogNoQuotes_{ijt}, and trading, LogNoTrades_{ijt}, margins. Our main test is whether morning quotes predict afternoon trades after controlling for morning trades. In addition, we test whether morning trades predict afternoon quotes after controlling for morning quotes.

Panel B of Table 9 reports our findings from specification (17). Columns 1/2 and 3/4 present results for the extensive/intensive margin. Having an AM *quote* by dealer i in bond j increases the PM trade probability by the same dealer in the same bond on the same day by 0.023 (2.3%,

Table 9: Predicting PM trades and PM quotes

The table documents the predictability of PM trades and PM quotes by AM quotes and AM trades. Panel A provides summary statistics. In Panel B, estimates are obtained from panel regressions with dealer fixed effects, bond fixed effects, and day fixed effects as specified in the respective column. Standard errors are triple clustered at the dealer, bond, and day level. Significance levels are *** 1%, ** 5%, * 10%.

Panel A: Number of trades and quotes AM and PM

Variable	Obs	Mean	Std. Dev.	Min	Max
No. trades AM	13,767,800	0.024	0.251	0	204
No. trades PM	13,767,800	0.042	0.526	0	316
No. quotes AM	13,767,800	0.127	0.601	0	28
No. quotes PM	13,767,800	0.052	0.440	0	28

Panel B: VAR

	(1)	(2)	(3)	(4)
	$\text{HasTrade}_{ijt}^{PM}$	$\text{LogNoTrades}_{ijt}^{PM}$	$\text{HasQuote}_{ijt}^{PM}$	$\text{LogNoQuotes}_{ijt}^{PM}$
$\text{HasQuote}_{ijt}^{AM}$	0.023***		0.217***	
	(0.005)		(0.040)	
$\text{HasTrade}_{ijt}^{AM}$	0.211***		0.023**	
	(0.009)		(0.009)	
$\text{LogNoQuote}_{ijt}^{AM}$		0.026***		0.358***
		(0.004)		(0.063)
$\text{LogNoTrade}_{ijt}^{AM}$		0.259***		0.015**
		(0.013)		(0.007)
fe	Triple	Triple	Triple	Triple
r2	0.067	0.077	0.189	0.331
N	13,767,800	13,767,800	13,767,800	13,767,800

Column 1). The result is statistically significant at 1% level. Having AM *trade* by dealer i in bond j increases the PM trade probability by the same dealer in the same bond on the same day by 0.211 (21.1%, Column 1). Increasing the number of AM *quotes* by dealer i in bond j from one to two increases the number of PM trades by the same dealer in the same bond on the same day by 2.6% (Column 2). The result is also statistically significant at 1% level. Increasing the number of AM *trades* by dealer i in bond j from one to two increases the number of PM trades by the same dealer in the same bond on the same day by 25.9% (Column 2). Therefore, AM quotes facilitate PM trading by the same dealer in the same bond on the same day even after controlling for trade persistence.

Having an AM *quote* by dealer i in bond j increases the PM quote probability by the same dealer in the same bond on the same day by 0.217 (21.7%, Column 3). The result is statistically significant at the 1% level. Having an AM *trade* by dealer i in bond j increases the PM trade probability by the same dealer in the same bond on the same day by 0.023 (2.3%, Column 3). Increasing the number of AM *quotes* by dealer i in bond j from one to two increases the number of PM quotes by the same dealer in the same bond on the same day by 35.8% (Column 4). The result is also statistically significant at the 1% level. Increasing the number of AM *trades* by dealer i in bond j

from one to two increases the number of PM quotes by the same dealer in the same bond on the same day by 1.5% (Column 4). Therefore, AM trades facilitate PM quoting by the same dealer in the same bond on the same day even after controlling for quote persistence.

In summary, there exists a strong lead-lag intraday relation between quotes and trades. Quotes are more prevalent in the morning than in the afternoon and tend to facilitate the afternoon trades by the same dealer in the same bond on both the extensive and intensive margins even after controlling for trade persistence.

7 Conclusion

Little is known about pre-transparency due to dealer quotes in OTC markets. We examine the relevance of indicative dealer quotes in corporate bonds. Market-wide higher quoting activity is associated with greater trading volume. At the dealer level, the presence of a quote is associated with higher propensity to trade with more and better quotes attracting more volume. These effects are larger when uncertainty is higher in terms of lower credit ratings and higher volatility, including the onset of Covid-19. Quote competition for order flow is associated with improved execution as clients receive better prices when more dealers quote and when the client trades with the dealer posting the better quote.

These findings establish two fundamental results that inform the state of the corporate bond market. First, dealers have incentives to post higher quality quotes. Second, customers have incentives to search across dealers to find the best price. Both effects are economically significant. While quotes are only indicative, our result suggest quote competition is important in corporate bonds.

Our study suggests that institutional clients benefit from quote competition. Indicative quotes used in the study are not generally available to retail investors and smaller institutions. Therefore, we cannot estimate the effects of broadcasting quote data to participants that currently have limited direct access to dealer quotes. However, our results are suggestive that smaller market participants may not be receiving the trading cost benefits attributable to quote competition. This would be consistent with Green, Hollifield and Schürhoff (2007)'s prediction that OTC dealers exercise market power, and with the empirical evidence that large trades have lower trading costs than small trades in corporate bonds.

One possibility to level the playing field is to trade the bonds on a consolidated and transparent exchange, similar to the mid-1990s Nasdaq market, along with best execution requirements for routing the order to the dealer posting a better quote or executing the trade at the best price. Using NYSE data from the 1940s, Biais and Green (2019) present evidence of active trading in corporate bonds on a centralized and transparent exchange. Along similar lines, Abudy and Wohl (2018) report that, in the Tel Aviv Stock Exchange, corporate bonds trade in a transparent limit order book structure and exhibit high liquidity. While these suggest it is feasible to trade bonds on a transparent exchange, in both instances small retail trades played an important role. Biais and Green (2019) suggest volume moved off-exchange when institutions became more important because institutions and dealers may prefer the OTC structure when the trading is infrequent and in larger size.

Another possibility is to create a system for consolidating quotes from dealers and electronic platforms and to widely disseminate information on the best available bid and ask quotes. However, many questions arise for such a system. Should the reporting of dealer quotes be voluntary or mandated? In the current market structure, dealers are endogenously selecting the list of potential institutional customers that receive the quotes, weighing the benefits (e.g., trading relationships and order flow) of sharing valuable information against the costs (e.g., adverse selection or information leakage) of doing so. Would mandatory disclosure of dealer quotes lower trading costs for investors? Or would mandatory disclosure reduce the production of quotation data that we show benefit the institutional clients when disclosures are voluntary?[16]

To mitigate the negative consequences of mandating quote disclosures, one approach is to compensate dealers for the value associated with quote production, potentially via data fees on consolidated National Bid and Offer quotes. This brings up the complex issue of the pricing of market data and the structure of the consolidated quote system. How would revenue be apportioned among quote providers (a contentious issue under Reg NMS for equity markets)? Who should be covered under mandatory quote disclosure and who should they report to? For mandatory reporting of trades, U.S. SEC-registered broker-dealers and trading platforms are required to report their transactions in Treasury, corporate, and structured bonds to FINRA. One solution could be to adopt an arrangement along the lines of FINRA's TRACE platform, although the issues are more complex for mandatory reporting of quotes. For example, unlike a trade which is well-defined, regulators need to define a quote that is subject to mandatory disclosure (O'Hara (2010)). Are indicative quotes covered or do quotes need to be firm? Are quotes submitted in response to a client enquiry via a RFQ system covered? What about quotes shared via voice communications or chats between dealers and clients?

While our results indicate that quote competition is important in corporate bonds, further study of related issues could deepen our understanding of the corporate bond market structure and OTC trading more generally. How do dealers decide what bonds and at what prices to quote? How do dealers decide who to disseminate their quotes to and when to update those quotes? How are quotes used in negotiations? How does the introduction of BondCliq's consolidated quote product affect dealers and customers? If dealer quotes are disseminated to other dealers does this increase quote competition or could it lead to non-cooperative collusion?

[16] Bloomfield and O'Hara (1999) and Madhavan, Porter and Weaver (2005) find that mandated pre-trade transparency can reduce liquidity.

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Appendix

Appendix A Data filters

A.1 BondCliQ Data Filter

Table A.1: BondCliQ data filters

The table documents the steps involved in filtering the BondCliQ data on dealer quotes. Quotes on the bid side and ask side are treated as separate quotes.

Step	No. quotes	No. bonds
Original (Oct 1, 2019–May 1st, 2020)	8,546,249	24,441
In FISD	6,526,786	13,477
Keep bond type "CDEB", "CZ", "CPIK", "CCOV", "CLOC", "UCID", "CMTN", "CMTZ", "EBON", "EMTN"	6,045,106	12,102
Not exchangeable, preferred or convertible	6,042,870	12,091
Drop government type or foreign	4,584,077	9,678
Drop if missing offering date, maturity, offering amt or offering amt<$100K	4,583,478	9,670
Drop floating rate	4,312,326	8,764
Drop maturity<1/1/2021 or maturity>12/31/2070 or payment-in-kind type coupon	4,229,643	8,113
Drop if price=spread	4,187,757	8,101
Drop bond trading holiday	4,183,125	8,101
Drop non-unique observation at timestamp, firm, cusip and quote side	4,170,931	8,101
Keep semi-annual interest payment or zero coupon	4,160,948	8,077

Appendix B Steps for converting quoted yield spreads to quoted prices

To measure the quality of the quotes, we first need to make sure all quotes are in prices. Many investment grade bonds are quoted in terms of yield spreads to the benchmark yields. When the bond is quoted in yield-spread space and a price quote is missing, we infer the price from the quoted yield spread. A key step is to identify/match the corresponding benchmark yield (not provided in the data). The steps are:

1. Match the bonds to benchmark securities based on tenor (2, 3, 5, 10, 30 years). We follow market convention in terms of the cutoffs of maturity dates for each tenor buckets.
2. Get intraday benchmark Treasury yields at 5 minute intervals from Bloomberg.
3. Match the bond spread to its benchmark yield based on the quote timestamp and the tenor.
4. Calculate yields by adding the quoted spread and the benchmark yields.
5. Convert yields to prices.
6. For callable bonds, we treat the quoted yields as yield to worst.

Appendix C Extra tables and figures

Table C.2: Importance of quote quality to attract order flow—alternate quote quality

The table documents the importance of quote quality to attract order flow. The dependent variable captures the trading activity by dealer i in bond j on day t by HasTrade_{ijt} or LogNoTrades_{ijt}. We measure quote quality using its distance to NBBO. Estimates are obtained from panel regressions with dealer fixed effects, bond fixed effects, and day fixed effects. Standard errors are triple clustered at the dealer, bond, and day level. Significance levels are *** 1%, ** 5%, * 10%.

	HasTrade_{ijt}			LogNoTrades_{ijt}		
	(1)	(2)	(3)	(1)	(2)	(3)
	All trades	Trade size ≥$100K	Trade size <$100K	All trades	Trade size ≥$100K	Trade size <$100K
$\text{QuoteQuality}_{ijt}$ (alternate)	0.019**	0.014**	0.010**	0.027***	0.023***	0.007**
	(0.008)	(0.007)	(0.004)	(0.007)	(0.005)	(0.003)
HasQuote_{ijt}	0.034***	0.028***	0.012***			
	(0.008)	(0.006)	(0.004)			
LogNoQuote_{ijt}				0.037***	0.032***	0.010***
				(0.006)	(0.005)	(0.003)
$\text{NoFirmsQuoting}_{jt}$	0.004***	0.003***	0.001***	0.003***	0.002***	0.001***
	(0.001)	(0.001)	(0.000)	(0.001)	(0.001)	(0.000)
y_{ijt-1}	0.221***	0.178***	0.196***	0.264***	0.206***	0.243***
	(0.011)	(0.007)	(0.014)	(0.015)	(0.008)	(0.020)
fe						
r2	0.102	0.063	0.089	0.123	0.075	0.109
N	13,673,500	13,673,500	13,673,500	13,673,500	13,673,500	13,673,500

Table C.3: Client execution quality and dealer quotes—alternate benchmark price

The table documents the impact on client execution quality of dealer quotes and quote quality. Estimates are obtained from panel regressions with dealer fixed effects, bond fixed effects, and day fixed effects interacted with a buy-sell indicator. Standard errors are triple clustered at the dealer, bond, and day level. Significance levels are *** 1%, ** 5%, * 10%.

Panel A: Descriptive statistics on ClientExecutionQuality$_{ijt}$ (alternate)

	N	Mean	SD	5%	25%	50%	75%	95%
ClientExecutionQuality$_{ijt}$ (alternate)	452,235	-0.29	1.18	-2.00	-0.46	-0.08	0.03	0.81
Trade size≥$100K	256,339	-0.19	1.25	-1.81	-0.38	-0.08	0.09	1.13
Trade size<$100K	195,896	-0.42	1.07	-2.07	-0.63	-0.09	0.00	0.36
IG rated	323,707	-0.26	1.10	-1.81	-0.38	-0.06	0.03	0.68
HY rated	128,528	-0.36	1.36	-2.31	-0.67	-0.17	0.03	1.19

Panel B: Impact of dealer's quote quality on ClientExecutionQuality$_{ijt}$ (alternate)

	(1)	(2)	(3)
	All trades	Trade size≥$100K	Trade size<$100K
QuoteQuality$_{ijt}$	0.415***	0.500***	0.064
	(0.056)	(0.063)	(0.074)
BenchmarkUpdate$_{jt}$	0.524***	0.574***	0.337***
	(0.047)	(0.046)	(0.038)
HasQuote$_{ijt}$	0.077***	0.045	0.059*
	(0.021)	(0.030)	(0.030)
AnyQuote$_{jt}$	0.099***	0.136***	0.014
	(0.029)	(0.044)	(0.022)
fe	Quad	Quad	Quad
r2	0.150	0.134	0.250
N	451,741	255,769	194,920

Panel C: Impact of market conditions on ClientExecutionQuality$_{ijt}$ (alternate)

	(1)	(2)	(3)
	All trades	Trade size≥$100K	Trade size<$100K
VIX$_t$	-0.864***	-0.717***	-1.109***
	(0.140)	(0.122)	(0.185)
QuoteQuality$_{ijt}$	0.098	0.207	-0.066
	(0.124)	(0.131)	(0.160)
QuoteQuality$_{ijt}$ × VIX$_t$	0.943**	0.888**	0.397
	(0.367)	(0.433)	(0.590)
BenchmarkUpdate$_{jt}$	0.512***	0.565***	0.321***
	(0.048)	(0.046)	(0.040)
DealerSellTrade$_{ijt}$	-0.052	-0.023	-0.084*
	(0.042)	(0.045)	(0.043)
HasQuote$_{ijt}$	0.071***	0.025*	0.069**
	(0.021)	(0.015)	(0.032)
AnyQuote$_{jt}$	0.106***	0.148***	0.008
	(0.022)	(0.032)	(0.023)
fe	Double	Double	Double
r2	0.116	0.086	0.230
N	451,741	255,769	194,920

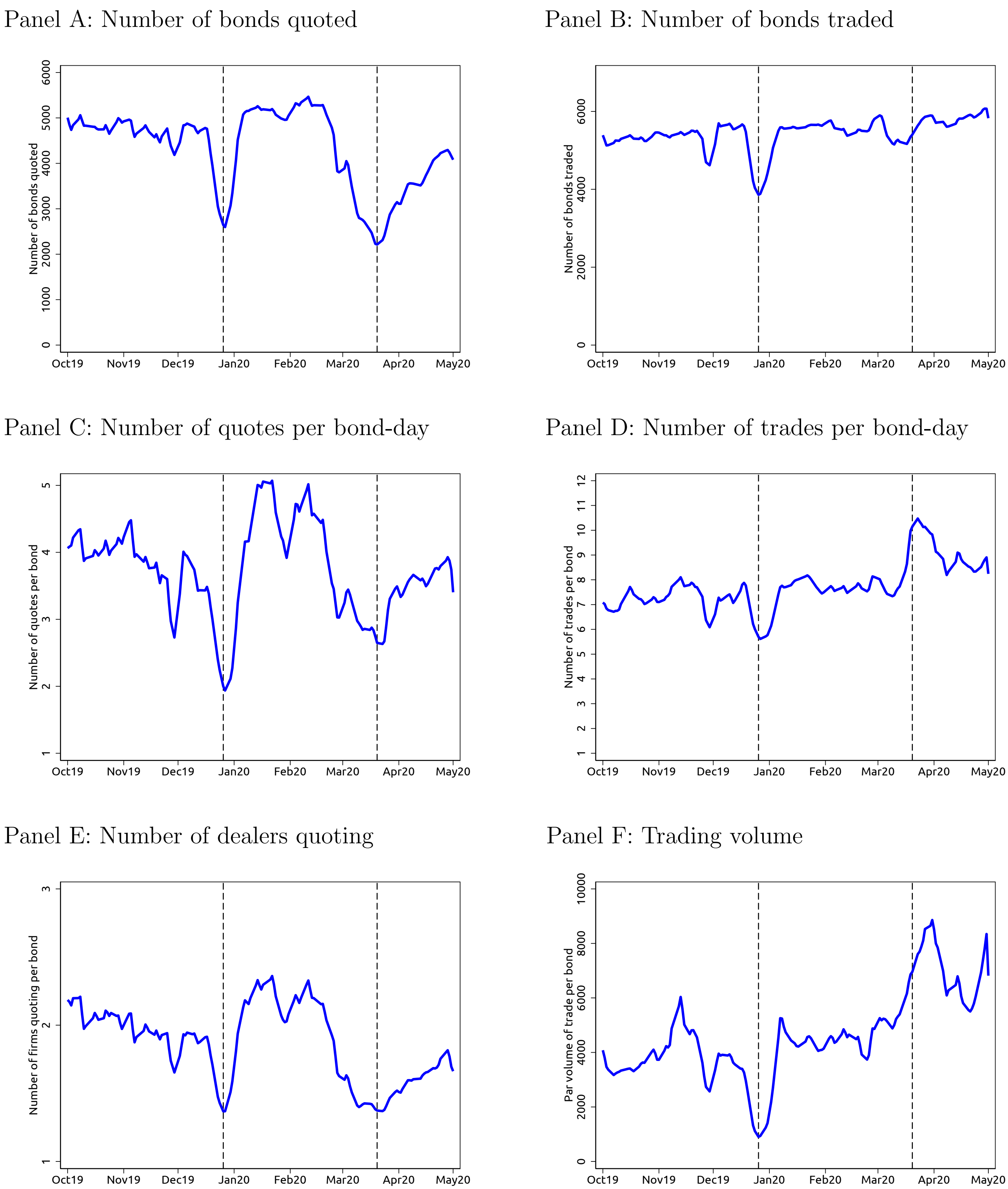

Figure C.1: Times series behavior of quoting activity

The figure documents the times series of quoting and trading activity. Each line corresponds to the daily sample average. The daily statistics are smoothed using a locally weighted regression. The dotted vertical lines correspond to December 26, 2019 and March 20, 2020, respectively.