Transaction Costs, Trade Throughs, and Riskless Principal Trading in Corporate Bond Markets

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Abstract

This study analyzes the costs of trading bonds using previously unexamined quotations data consolidated across several electronic bond trading venues. Much bond market trading is now electronic, but the benefits largely accrue to dealers because their customers often do not trade at the best available prices. The trade through rate is 43%; the riskless principal trade (RPT) rate is above 42%; and 41% of customer trade throughs appear to be RPTs. Average customer transaction costs are 85 bp for retail-size trades and 52 bp for larger trades. Estimated total transaction costs for the year ended March 2015 are above $26 billion, of which about $0.5 billion is due to trade-through value while markups on customer RPTs transfer $0.7 billion to dealers. Small changes in bond market structure could substantially improve bond market quality.

Keywords: Bond market liquidity, transaction costs, riskless principal trades, trade throughs, effective bid/ask spreads, dealers, brokers, pre-trade transparency, TRACE.

JEL Classification Codes: G12, G19, G24, G28

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Author's disclosures: 1) I am the lead independent director of Interactive Brokers (IB) from which I obtained much of the data used in this study. IB potentially could benefit from some results and recommendations in this study. IB did not compensate me for undertaking any part of this study; IB did not request the study; IB had no control over the study; the production of studies such as these is not an expected part of my responsibilities as director at IB; and IB has not provided me any compensation for any work besides my normal director's fees for more than 10 years. 2) The University of Southern California is a large corporate bondholder and could potentially benefit from some results and recommendations in this study. I had no contact with any USC investment staff concerning these topics before or during the production of this study. 3) I do not own any publicly traded bonds or bond funds except a small position in TIAA Traditional purchased in 1982-83. 4) I serve as a director of the various Selected Funds, and as a trustee of the Clipper Fund, all managed by Davis Select Advisors, a value equity manager. These equity mutual funds do not normally hold corporate bonds. Davis Select Advisors undoubtedly selects and trades corporate bonds for its other clients, but I am unaware of these activities. 5) I serve as a director of a small endowment fund that holds corporate bonds. The manager and the other fund directors were unaware of this study while I was producing it. 6) Since completing the first draft of this study, KCG BondPoint contracted with me to speak about bond market structure at a client conference. KCG has had no control over this study.

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1 Introduction

Brokers are supposed to obtain the best available prices for their clients. They fail to do so when they arrange trades at inferior prices to those that are readily available. For example, if a broker arranges a bond purchase for a client at 101 when some trader is willing to sell at 100, the broker will not have obtained the best available price. Such trades are called trade throughs. A trade through is a purchase at a price greater than the best (lowest) available offer, or a sale at a price below the best (highest) available bid. Trade-through value is the dollar value of the benefit that traders who received inferior prices would have obtained had they traded at quoted prices. It is the absolute difference between the trade price and the quoted price times the minimum of the trade size and the quoted size.

Using quotation data consisting of the best bids and offers collected by Interactive Brokers (IB) from a variety of market centers, and bond trade price data from FINRA's TRACE bond price reporting system, I estimate transaction costs for most trades in the U.S. corporate bond markets and identify many trade throughs. With these results, I then obtain econometric estimates of total transaction costs and total trade-through values for the entire market. The results have strong implications for how bond markets should be structured and regulated.

I find that average transaction costs that customers incur when trading range between 84.5 bp for retail-size trades ($100,000 or less in par value) and 52.1 bp for larger trades. These costs are several times larger than costs for similar size trades in equity markets. Trades occurring in markets with two-sided quotes that have stood at least two seconds trade through 46.8% of those markets; 40.8% of these trade throughs appear to be riskless principal transactions—trades for which the dealer has no inventory risk exposure usually because the dealer simultaneously offsets a trade with a customer with an interdealer trade. RPT transactions account for more than 41.7% of all trades. Total transaction costs borne by customers in U.S. corporate bond markets for the year ended March 31, 2015 are at least $26B, of which about $0.5B is due to trade-through value. During this period, markups on customer RPTs transferred $667M to dealers.

This paper helps inform a growing debate on the future of bond markets in the United States. Electronic trading has substantially improved equity markets, but from the outside, it seems to have had little effect on bond markets.[1] All five sitting commissioners of the U.S. Securities and Exchange Commission have identified bond market structure issues as worthy of further attention.[2]

Trade Throughs

Many trade throughs occur when a broker adds a markup to the trade price, and many of these trade throughs occur in the normal course of business because bonds generally are traded net and often not with commissions. The markup serves as a commission to compensate the broker-dealer for arranging the trade. The results in this study show that many of these markups are high.

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[1] For evidence on the U.S. equity markets, see Angel, Harris, and Spatt (2011, 2015).
[2] See White (2014), Aguilar (2015), Gallagher (2014), Piwowar (2015), and Stein (2014).

For example, suppose that a broker-dealer buys a bond at the best available quoted price of 100 on behalf of a client and then sells it to the client at 101, a markup of 1. Such transactions are called riskless principal trades (RPTs) because the broker-dealer arranges two offsetting trades that produce a riskless profit—the markup. In these transactions, the broker-dealer typically trades with another dealer first (who provided the quote), and then trades with the client. Although this transaction might not strictly be a trade through (it would not be if the broker-dealer exhausts all the size at the quoted price), the broker-dealer clearly is front-running the customer order, though not necessarily illegally. The economic consequence to the customer is the same regardless of the characterization of the trade.

Trade throughs also occur when a broker-dealer trades with a client at a price inferior to one available elsewhere. Such trades may be risky to the dealer if the dealer is committing capital (trading for its inventory account). But most dealers immediately offset these trades by taking the better price offered elsewhere because doing so guarantees that they profit with little risk. For example, if the broker sells a bond to a client at 101 and then buys it back at the best available price of 100, the trade is not a RPT (as described above) because the opportunity to buy at 100 may disappear (either because the seller cancelled the order or another buyer took the opportunity) before the dealer can take it. But the risk in these proprietary trades is very small. It depends on how quickly the broker can access the best opportunity to buy. When using electronic systems in markets without much competing activity, the risk is very small. Although these trades are not strictly RPTs, they essentially are, and most market participants regard them as such. Accordingly, many analysts would consider the profits in these trades as essentially the same as the markups in the true RPTs described above.

Trade throughs also may occur when a broker routes an order to a dealer in exchange for payment-for-order flow, a practice called preferencing. If the dealer receiving the order trades through a better price, the broker clearly will not obtain the best available price for the client. In this scenario, the receiving dealer will likely take the better price, and transfer some of the riskless profits to the broker through the payment for order flow. In such trades, clients generally do not know the size of the markups or of the payments for order flow. This study does not identify these trades which are known to be common.

Regulatory Issues Associated with Markups

Markups and commissions both contribute to transaction costs. Markups are incorporated in the price whereas commissions are tacked onto the price. Both allow brokers to recover the costs of arranging trades, and presumably all other costs of providing trading services to their clients.

If markups were fully disclosed as commissions are, RPTs essentially would be agency trades for which the client pays a markup instead of (and sometimes in addition to) a commission. With full disclosure, clients could choose their brokers based on the markups or commissions that they apply to their trades, among many other factors.

Markups differ from commissions because broker-dealers generally do not fully disclose markups to their clients. Accordingly, clients may have trouble determining whether they have obtained the best available price, and especially when clients are not fully aware of the difference between the trade prices received and the best available prices. Under these conditions, clients cannot judge whether the markups that they pay are commensurate with the transaction services they receive, or simply profits taken by broker-dealers acting in violation of the normal agency relationship.

Broker-dealers may argue that in a riskless principal transaction, they act as dealers and not as brokers, and thus are not under any obligation to deliver the best available prices to their clients. If so, clients must know the prices at which they could trade with others to determine whether their dealers are offering good prices. Such information is difficult to acquire without systems that publicly disseminate the prices at which other traders are willing to trade. In U.S. corporate and municipal bond markets, little such pre-trade transparency exists.

Even when broker-dealers fully disclose the nature of their relationships with their clients—that they are acting as principle and not as agent—many clients may not recognize the distinction and its implications. The distinction can be difficult to recognize when the broker-dealer sometimes acts as broker and sometimes as dealer, a process commonly called dual trading.

When customers cannot easily make these distinctions, regulators may want to intervene. Regulators could require that

- Clients somehow be better informed—perhaps through better disclosure or through better educational initiatives,
- Brokers be prohibited from dealing to their clients, i.e., no dual trading, or
- Better pre-trade transparency information systems be made available to clients.

Pre-trade Transparency
Many trade throughs occur simply because brokers often are unaware of better prices due to the low level of pre-trade price transparency in most corporate and municipal bond markets. Some trade throughs occur simply because brokers do not post their customers' limit orders in places where other brokers and dealers could see them. Many trade throughs thus might be avoided with better pre-trade transparency, perhaps through rules that require traders to post limit orders of willing customers to venues (order display facilities) that widely disseminate these prices.

This Study
Whether these issues should concern investors and regulators depends on how common trade throughs are, how large are their associated markups, and the extent to which customers are aware of these quantities. This study measures trade throughs and markups using direct and indirect methods.

The direct methods compare corporate bond trade prices to pre-trade records of quotes and price indications that IB obtains from several electronic trading venues. The indirect methods imply trade throughs from analyses of pairs of trades identified as RPTs in the TRACE corporate bond trade data base.

Both methods have their advantages and their shortcomings. Since neither method can identify all trade throughs, the results only provide lower bound estimates of trade through rates and of the associated markups, and not actual tabulations of these quantities. Regardless, these estimates are quite informative. Actual quantities are almost certainly higher.

Organization of the study
The next section describes the empirical strategies used in this study and how they depend on available data. Section 3 provides a short review of related literature. The presentation of the empirical results

starts in section 4 with characterizations of bond trade and quotation frequencies in the TRACE and IB data sets. Sections 5, 6 and 7 then respectively present transaction cost results, trade though results, and results concerning riskless principal trades. Results characterizing the empirical relation between these two trade types appear in Section 8. The final results appear in Section 9 which describes my estimates of total annual transaction costs and trade-through values. The paper concludes with a discussion of the implications of the results for public policy in Section 10.

2 Empirical Strategies and Data Considerations

Trade throughs can be identified either directly by comparing trade prices to pre-trade quotes and price indications, or indirectly by identifying RPTs. Both methods have advantages and disadvantages.

2.1 Direct Identification of Trade Throughs

The advantage of directly identifying trade throughs by comparing trade prices to pre-trade quotes and price indications is that this method most clearly answers the question of interest: To what extent are trades taking place at prices inferior to those available elsewhere? The problems with this identification method are two-fold:

First, data on pre-trade quotes and price indications presently are hard to come by and incomplete. Accordingly, analysts cannot identify all trade throughs among a given record of trades because many quotes and price indications may not be available. This consideration suggests that a study of trade throughs will fail to identify many trade throughs to the extent that the pre-trade data are incomplete.

The second potential problem is that pre-trade data often consist of indications rather than firm quotes. Indications are messages placed by dealers indicating that they are willing to trade at given prices. The actual prices at which they trade may be better or worse when they arrange their trades. In contrast, a firm quote is a standing order provided by a trader that other traders can take when they want to trade. Unless such trades are subsequently broken (which is extremely uncommon), these orders represent true trading opportunities. Accordingly, identifying trade throughs using firm quotes is more reliable than identifying trade throughs using price indications. The latter are only reliable to the extent that the indications are honored. Unfortunately, many bond trading systems that collect pre-trade price information collect indications rather than firm quotes. However, most of these indications are firm because dealers benefit from cultivating a reputation for honoring their quotes.

2.2 Indirect Identification of Trade Throughs via Riskless Principal Trades

Riskless principal trades are easy to identify when trade data include the identities of the parties to a trade. These data generally are available to regulators, but rarely to academic researchers.

Fortunately, even without information identifying trade counterparties, examinations of trade prices can identify many (but not all) RPTs. A RPT very often appears as two trades in the same bond of the same size at approximately the same time. If one such trade is between a dealer and a customer (a “customer trade”), and the other trade is between a dealer and another dealer (an “interdealer trade”), and the reported prices are different, the pair likely represents a RPT in which the dealer traded with the client and then offset the trade with another dealer, or vice versa. A pair of trades consisting of an interdealer trade and a customer trade reported exactly at the same time with the same price and size is most likely an agency trade in which the dealer-broker arranged a trade on behalf of its client.[3]

If these two trades occurred close together in time, and if the customer trade occurred at an inferior price to the dealers' interdealer trade with another dealer, the customer's trade may have traded through the other dealer's price. However, note that these situations also can arise when the other dealer was not posting a firm quote or price indication. In particular, the dealer in the middle may have arranged the trade by asking for a quote from the other dealer and then marking it up for the customer.

A pair of trades close in time and of the same size also may be a RPT if one trade is marked as a dealer buying from a client, and the other trade is marked as a dealer selling to a client. In which case, the pair likely represents a RPT in which the dealer bought from one client and sold to another client. If the dealer sold at a lower price than the dealer bought, the dealer's markup will contribute to the dealer's revenue for arranging the trades (the dealer might also receive one or more commissions). If one of the customers gave an order or indication to the dealer, and if the dealer markup is positive, the other customer's trade may be interpreted as trading through the first customer's price.

This indirect method fails to identify RPTs (and thus potential trade throughs) when the dealer accesses two or more quotes to fill a customer order, or when a dealer simultaneously fills several customer orders when trading against the same quote. The latter situation may occur when a broker-dealer, who has investment discretion over several client accounts, trades for many accounts at the same time. The method also may fail to identify RPTs if the sample selection criteria used to construct the TRACE sample (discussed below) exclude one or more reports of trades involved in a RPT.

The advantage of using this indirect riskless principal method for identifying trade throughs is that the method does not depend on knowing quoted or indicated prices, and it can be applied to a complete records of all trades.

The disadvantage of the method is that not all trades identified as trade throughs by this method will indeed be trade throughs due to any of the following scenarios:

- Some trades may not be RPTs, much less trade throughs, if by coincidence, two dealers report unrelated trades of the same size at approximately the same time.
- Even if the trades are RPTs involving the same dealer, the existence of a positive markup does not imply that one side or another provided a firm quote or indication to anyone. Instead, the dealer may have arranged the trade by negotiating with one or both sides of the trade.
- The method will fail to identify RPTs (and thus a potential trade through) if by chance another dealer reports a trade after the report of the first trade in an RPT and before the report of the second trade. If the trade is of a different size than the size of the RPT, then the analyst may fail to identify the RPT. If the size of the intermediate trade is the same as that of the RPT, the analyst may fail to identify the RPT, or the analyst may incorrectly identify one of the two legs of the RPT.

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[3] See "How to Report Agency Capacity Transactions" on page 27 of FINRA's TRACE User Guide.

- The RPT may be arranged at the best quoted bid or offer, or at an improved price.

Although these alternatives can explain why an RPT may not be a trade through, all but the last alternative loses credibility when the time interval between the two trades is short.

3 Related Literature

3.1 Transaction Cost Estimates

Harris (2003) and Harris (2015) present general discussions of the effective half-spread trade transaction cost measurement method used in this study.

Almost all previous studies of bond transaction costs estimate costs from bond transactions. This study is the first study of which I am aware to use continuous intraday quotation data.

Hong and Warga (2000), Kalimipalli and Arthur Warga (2002), and Chakravarty and Sarkar (2003) compute same-bond-same-day effective spreads by comparing purchase prices with sales prices. This method requires at least one trade on each side of the market during a given period and thus does not work well for inactively traded bonds.

Schultz (2001) introduces a method that estimates bond costs using regression methods applied to a buy/sell indicator and the difference between transaction prices and a benchmark price. It can measure transaction costs for inactive bonds but the quality of the results depends on estimating difficult-to-estimate benchmark prices, which is particularly difficult for high yield bonds. Bessembinder, Maxwell, and Venkataraman (2006) estimate a variation of the Schultz model that incorporates company-specific information, which allows them to estimate transaction costs for high-yield bonds. Goldstein, Hotchkiss, and Sirri (2006) use a method similar to Schultz (2001) to estimate transaction costs for a sample of BBB-rated bonds. These studies all require that the trades studied are identified as to buyer and seller. Their data sources thus come from institutional traders or their consultants.

Harris and Piwowar (2006) develop a different regression approach to study secondary transaction costs for municipal bonds based only on trade reports. Their model identifies costs based on the identification of dealer sides. They apply the model to a large sample of municipal bond trades obtained from the Municipal Securities Rulemaking Board (MSRB). Edwards, Harris, and Piwowar (2007) apply this econometric method to the corporate bond markets using TRACE data obtained from FINRA, which then was known as the National Association of Securities Dealers (NASD).

In November 2008, TRACE started to publicly disseminate the reporting party side of all dealer trades. (Edwards, Harris, and Piwowar obtained these data directly from the NASD.) These data allow the customer trades in TRACE to be signed. Ciampi and Zitzewitz (2010) use this information to estimate bond transaction costs during the Financial Crisis.

These studies show that transaction costs per bond decrease with trade size and increase with credit risk, among many other issues. This study confirms these results.

Finally, Adrian, Fleming, Shachar, and Vogt (2015) analyze TRACE data to determine whether spreads have declined over time. On a daily basis, they estimate spreads for each investment-grade bond as the difference between the average prices at which dealers sell to and buy bonds from their customers. They then average these spreads across bonds and days. Their results show that investment-grade bond spreads presently are about 75bp and that they steadily declined since peaking during the financial crisis. Their results suggest that the growth in electronic trading in the bond markets has lowered transaction costs as Angel, Harris, and Spatt (2011, 2015) showed it did in the equity markets.

3.1.1 Transaction cost estimates from quote data

Using an econometric model, Fulop and Lescourret (2009) provide estimates of effective bid/ask spreads for 18 single-name credit default swaps using quote data obtained from GFI, a major CDS interdealer. The data come from GFI's CreditMatch electronic platform which maintains a continuous open limit order book for contracts of minimum size $1M. The econometric model is necessary because the quote data that they analyze do not include series of best bids and offers. The data also do not include trade sizes.

Biswas, Nikolova, and Stahel (2014) use indicative bid and ask CDS quotes from Markit to augment a regression model similar to that used in Schultz (2001) to estimate effective spreads for 851 single-name credit default swaps. They find that transaction costs are smaller than, and only weakly correlated with, quoted spreads.

Das, Kalimipalli, and Nayak (2014) examine TRACE data to determine whether measures of liquidity changed with the growth of CDS trading. Unlike in this study, their measures all characterize average liquidity in various bonds, and not the costs of a given bond trade.

Biais and Declerck (2013) estimate effective and realized spreads for individual bond trades using a quotes and trades dataset from the International Index Company and the International Capital Market Association from 2003 to 2005. Although the International Index Company publicly disseminates indicative bids and asks from 10 dealers every minute for hundreds of Sterling and Euro-denominated bonds, the quotes made available to Biais and Declerck only include daily closing quotes. Nonetheless, they find much smaller spreads for Euro-denominated bonds than I or others find in TRACE data. The difference probably is due to the continuous dissemination of the indicative quotes. Biais and Declerck report that market participants confirmed to them that the quotes "are quite representative of actual market pricing for institutional-size trades."

This study uses intraday quotation data consolidated from many market centers to directly estimate the effective bid/ask spread transaction costs for all bonds for which quotation data are available, regardless of trading frequency or risk. These data also permit an examination of bond market structure, and in particular, of trade through rates and of their relation to riskless principal trading. The results provide the most accurate and detailed characterization of U.S. corporate bond trading costs to date.

3.2 Price Transparency

Bessembinder and Maxwell (2008) provide a general discussion of transparency in corporate bond markets and of the related literature.

Several academic studies address issues associated with post-trade transparency. Most notably, Bessembinder, Maxwell, and Venkataraman (2006), Harris and Piwoar (2006), Goldstein, Hotchkiss, and Sirri (2006), and Edwards, Harris, and Piwowar (2007) consider how post-trade transparency affected transaction costs for the first groups of bonds for which FINRA and the MSRB reported trade prices to the public starting in 2002. Dealers were opposed to the public dissemination of trade prices and generally hoped that studies would show that the trade reports were damaging the market. Instead, these academic studies showed that the public benefited from post-trade transparency. With these results in hand, FINRA and the MSRB continued to phase-in real-time publication of TRACE and MSRB trade data for most corporate and municipal bonds.[4]

Green, Hollifield, and Schürhoff (2007) present theoretical arguments for greater transparency along with some empirical evidence. Their work shows that opaque markets increase dealer bargaining power. More generally, Duffie, Garleanu, and Pedersen (2005) provide a theoretical model of trading in OTC markets that identifies origins of market power.

Biais and Green (2007) show that exchange-listed bond trading was quite liquid in municipal bonds before the late 1920s and in corporate bonds before the mid-1940s, and that transaction costs then were lower than they are now. The proliferation of electronic bond trading systems has the potential to substantially lower bond transaction costs, presumably to levels lower than Biais and Green document given the well-known economic efficiencies associated with electronic trading. Harris (2015) provides a survey of these efficiencies.

Harris, Kyle, and Sirri (2015) argue that the introduction of a public order display facility to bond markets would substantially lower transaction costs for public investors. The results in this paper suggest that simply disseminating a consolidated bond quote feed similar to the facility that IB provides to its clients might significantly improve markets, especially if dealers could not trade through electronically accessible quotes.

The quotes used in this study are not generally available to the public, though they are available to IB's customers in real-time. This study thus cannot provide an empirical examination of the effect of making pre-trade price data available to the public on transaction costs, as did some of the above studies concerning post-trade transparency. However, by characterizing trade through rates and values, and the dollar value of RPT markups, this study provides important data that policymakers should consider when deciding whether bond markets should be made more ex-ante price transparent.

3.3 Riskless Principal Trades

Zitzewitz (2010) identifies RPTs, which he calls "trade pairing," in the TRACE data using similar methods to those presented in this study. He finds that RPTs are very common (46% of trades under $100,000) and that they are mostly small trades. These results are similar to those obtained in this study.

Sirri (2014) identifies RPTs in municipal bond trades using similar paired trade methods to those that Zitzewitz uses. Sirri extends those methods to identify RPTs for which size on one side or the other is broken up into several trades. His study characterizes the frequency of these RPTs and their markups, which he calls "price differentials."

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[4] See the TRACE Fact Book at http://www.finra.org/sites/default/files/2014-TRACE-Fact-Book.pdf (page 4) for a time-line of phase-in.

This study characterizes the relation between RPTs and trade throughs. This information has strong public policy implications for bond market structure.

4 Data and Data Characterizations

This study examines post-trade TRACE corporate bond trade data from FINRA and from an internal record of best bids and offers from a variety of electronic platforms complied by Interactive Brokers (IB).

The analyses examine two sample periods. The primary analyses consider the period from December 15, 2014 to March 31, 2015 ("Primary Period") since both data sources span this 73-trading day period. These analyses only examine CUSIP-days for which TRACE and IB recorded at least one trade and quote, respectively. Other analyses examine all 252 trading days in the one-year period from April 1, 2014 to March 31, 2015 ("Full Year") to estimate total transaction costs and values-traded through for all bond trades in TRACE.

4.1 TRACE

Dealers must report their secondary market corporate bond trades to FINRA through its Trade Reporting and Compliance Engine (TRACE) within 15 minutes of trade execution. FINRA disseminates the TRACE data to the public with a 15-minute lag. These data indicate the time, price, and size of all corporate bond trades in the United States. TRACE reports actual trade sizes for trade par values of $5,000,000 or smaller for trades in investment grade bonds and for values of $1,000,000 or smaller for speculative bonds, and it provides markers ("1MM+" and "5MM+") for larger trades. Although FIMRA knows the identities of the reporting dealers, they are not available to academic researchers. The full sizes of TRACE trades are available with an 18-month lag via FINRA's Enhanced TRACE product, but these data do not yet span the IB quote data that IB sent me. I obtain archived TRACE data for this study through Wharton WRDS.

The time-stamps of the TRACE trade reports are in seconds and not more precisely expressed. Since the sequence in which trades were reported is important in this study, all sorts of the TRACE trade reports preserve their original ordering for all trades that have the same sort key values.

Starting in November 2008, a marker appears in TRACE that shows whether the reporting dealer sold to a customer (S), bought from a customer (B) or traded with another dealer (D). Dealers report trades arranged by exchanges and by alternative trading systems as dealer trades.

The TRACE data in the Primary Period include 3,155,063 original trade reports, 43,314 reports of trade cancellations (1.4% of all original trade reports), and 42,965 corrected trade reports (1.4%). Multiple correction records occasionally appear for the same original trade, and a cancel record occasionally cancels a previously corrected trade. Trades appear in 24,110 different CUSIPs on 517,937 CUSIP-days spread over 93 calendar days, many of which are weekends and holidays.

4.1.1 Cancelations, Corrections, and Report Times

The TRACE data available to the public do not indicate how the trades were arranged, and in particular, which trades were arranged in electronic venues. I infer some information about how the trades were arranged by analyzing how quickly traders report trades and how quickly they report corrections and cancelations of trades previously reports.

Almost all (99.4%) original trade reports occur on the day of the trade (Table 1). In contrast, about one-quarter of the cancel and correction reports occur on a later day (26.0% and 24.6% respectively). For reports made on a subsequent day, the median numbers of calendar days to report are respectively 1, 2, and 1 days for original trade reports (which are late), cancel reports, and correction reports.

A disproportionate number of the cancellations, and to a much lesser extent corrections, involve customer trades (Table 2). Customer trades account for 65.3% of the original trade reports but they account for 76.5% of all cancellation records and 67.3% of all correction records. Cancelled dealer purchases from customers account for most of the cancellation rate disproportionality. Among cancel instructions, 40.2% involve dealer purchases from customers; the same rate among original trade reports is 28.8%. The disproportionality appears among trades of all sizes (results not reported in the tables). The disproportionality might be due in part to customers who cannot deliver bonds that they have asked their brokers to sell.

As noted above, traders cancel or correct about 2.8% of their original trade reports. These rates may reflect the fact that traders still manually arrange many of their trades. Alternatively, these rates may show that some automated trading is against indicative prices that are not firm, though this seems unlikely as traders generally would not report trades until they are sure that they have occurred. If they do, traders would have to cancel or correct such trades should their counterparties be unwilling to honor their indications.

An analysis of the distribution of the time interval between the trade execution and its subsequent original report helps identify why cancellations and corrections occurred and how traders arrange their trades. In particular, trades that report soon after they occur more likely may be electronic trades than manual trades. If cancellation and correction reports are more common for these trades than for other trades, their cause may be reliance on indicative quotes.

Unfortunately, the public TRACE data do not report the times at which the TRACE system receives trade reports and reports of trade cancelations and corrections. However, since all records have a daily sequential identifier attached to them, I can infer the report times with some accuracy from the execution times of the original trade reports. In particular, under the assumption that reports must always follow executions, all TRACE reports that follow the report of a trade (in sequential identifier order) must have occurred after the execution time of that trade. This observation allows me to place bounds on the earliest times at which reports could have be made.

I find these lower bounds using the following algorithm: First, I sort the records by report date and sequential identifier.[5] For each report date, starting with an assumed lower bound of 8:00 AM (when the TRACE system opens) as the earliest time that any report could have been made, I step through the

[5] TRACE reports missing values for report dates (TRACE field trans_dt) for all records through September 30, 2014. Some of these records appear in the Full Year sample but fortunately not in the Primary Period sample. Records with report dates later than their reported trade execution dates (trd_exctn_dt) appear after this date in the TRACE data. These records include late trade reports (46%), cancellations (29%) and corrected trade reports (25%).

sample looking for trades with reported execution times greater than the current lower bound for the report time. When I find such a trade, I increase the lower bound to the execution time of that trade. In this way, I assign a lower bound for the report time of every trade, cancellation, and correction report. The lower bound will be very good when the bond market trades actively and when many traders report their trades immediately. It will be poor when the market is slow or when traders report trades slowly.[6]

I use a similar method to assign upper bounds for the report times based on the assumption that no regular trade report should have been reported more than 15 minutes after its execution. Accordingly, the report time of a TRACE record can be no later than 15 minutes after the reported execution time of any subsequently reported trade record. This bound is most accurate when traders deliberately wait until a moment before 15 minutes to report their trades. Such behavior may be common for large trades (evidence presented below suggests that it is not), but it is not likely for small trades. Accordingly, this upper bound will be a noisy bound in comparison to the lower bound.[7]

For all trades in the final sample for which the trade was reported on the execution date during normal market hours and not marked as reported late, the median time between the upper bound and the lower bond is 246 seconds (Table 3).[8] As expected, the median time from execution to report is smaller for the lower bound than for the upper bound (7 seconds versus 283 seconds) and the standard deviation of these interval lengths is smaller for the lower bound (224 seconds) than the upper bound (258 seconds). These results suggest that the lower bound provides a better measure of report time than does the upper bound.[9] All subsequent timing results use this bound.

The time interval from trade execution to trade report can indicate how common electronic trading is. Among the trades occurring during normal trading hours, 56.0% were reported within 10 seconds—an interval sufficiently short that it very likely implies electronic order handing (Table 4). The rate decreases from 60.4% for trades under $100,000 in par value to 34.8% for trades with reported trade sizes above $5 million. The median interval increases from 6 seconds for the smallest trades to 41 seconds for the largest trades. These results suggest that larger trades are more likely negotiated manually than are smaller trades. Traders who deliberately delay their larger trade reports may also explain these results.

Traders reported 74.0% of all cancellations and 75.4% of all corrections on the day of the original trade report (Table 5). Only 1.8% of the cancel reports and 2.2% of the correction reports that were reported on

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[6] The lower bound assumes that all traders do not uniformly delay their reports. If they do, the actual report times will be higher than the lower bound.

[7] To compute this bound, I sort trades by descending sequence number. Starting with an upper bound of 6:30 PM for the report time (the time the TRACE system closes), I then work forward through time and change the upper bound whenever I encounter a trade report with an execution time of less than 15 minutes before the current upper bound.

[8] The minimum time between the two bounds should be 0 seconds, but it is -3 seconds for 28 records with arrival sequence numbers 33,546 to 33,573 on report date (and transaction date) Jan 22, 2015. The cause appears to be trade report number 33,573 that appears to have been reported late by at least three seconds (15:03 after the trade time) but which was not marked as such. Nothing about these trades or the trades that immediately preceded or followed them otherwise appears to be out of the ordinary. I marked this trade record as a late trade report.

[9] The average between the lower and upper bounds could provide a better measure than either of the bounds if their estimation errors were sufficiently independent, but its performance lies in the middle between the two bounds.

the day of the trade were reported within 10 seconds of the reported trade time; 46.9% and 53.1% were reported with a lag of more than 15 minutes. The median times to cancellation and to correction are 765 seconds and 492 seconds, respectively. These results suggest that the cancellation and correction processes generally depend on human intervention at some point.

Table 6 presents distributions of the elapsed time between trade execution and original trade report, classified by whether the trades were subsequently cancelled or corrected. The median time to first report is longer for trades that were subsequently cancelled (20 seconds) or corrected (14 seconds) than for those that were never changed (8 seconds). This result suggests that subsequently changed trades more likely were arranged manually than by electronic systems. The cancellations and corrections thus may be more likely due to trader errors rather than to automated trading against indicative prices that are not firm, as suggested above. The latter explanation would imply faster original trade reports for the subsequently cancelled and changed reports.

The median time to initial report of trades that were subsequently corrected is smaller for interdealer trades (11 seconds) than for trades dealers arranged for customers (18 seconds). This result suggests that dealers use automated trading systems when arranging trades with each other more than they use them when arranging customer trades. This difference between interdealer and customer trades is smaller for trades that subsequently were cancelled. These trades may have more likely been arranged using manual systems.

The means of these distributions are two orders of magnitude larger than their medians, which indicates that these distributions have very fat right tails. Of the trades that were subsequently cancelled, 11.8% were originally reported more than 15 minutes late, which is longer than TRACE permits. This evidence suggests that many of the problems that led to the cancellation of these trades apparently were present when the trades were first arranged.

Among trades with corrected records, 40.8% corrected trade prices, 17.5% corrected trade sizes (some corrected both), and 2.8% corrected execution times (Table 7). The remainder corrected various trade status indicators. Increases and decreases were about equally common for both prices and sizes. All but one of the corrected execution times report earlier times than appear in the original trade reports.

The fact that size decreases are not more common suggests again that the indicative prices are quite firm. If the corrections were due to unavailable size, decreases would be more common.

4.1.2 Sample Filters

I remove all of the cancelled trades and I apply all the corrections.[10] These changes decrease the identification rate for RPTs when one of the two trades in a RPT pair is cancelled or has a corrected size.

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[10] The correction and cancellation records ("change records") include a field that points to the record sequence number of the record to be cancelled or corrected, but unfortunately, FINRA restarts those sequence numbers every day, and the change records provide no record date that points to the record date of the target record to be changed. Accordingly, since change records sometimes change previous change records that were reported on a day subsequent to the trade date, a change record could point to more than one target record. I solve this problem by requiring that change and target records match exactly in their CUSIPs and their trade dates. With this requirement,

Removing cancelled trades and applying corrections ensures that only trades that actually settled contribute to the results, and in particular, that trades mistakenly ordered, or executed at mistaken and perhaps unrealistic prices or sizes, do not affect the results. The removal of cancelled trades (1.29%) leaves 3,111,771 trades (of which 1.28% are corrected) in 23,890 CUSIPs traded on 513,652 CUSIP-days.

I exclude all trade reports where the time of trade is outside of the normal 8:00 AM to 5:15 PM ET trading hours[11] or when the reported trade execution date was on a weekend (a few hundred, almost all on Sundays) or a bond market holiday (very few).[12] These filters remove 1.83% of the original trade reports, 0.54% of the CUSIPs, and 1.45% of the CUSIP-days.

Additional filters remove various types of irregular trades. These trades include trades with sales condition codes that indicate cash sales, next day settlement, or weighted average price trades; trades with special price flags that indicate that a debt security that conventionally is traded at a price that reflects a due bill or warrant in the transaction reported traded without the due bill or warrant so that a price

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the mapping is unique, though somewhat difficult to implement because the records must be "daisy-chained," and because different changes to two or more trades that were reported in the same bond on the same trade day require that the record updating procedure handle multiple instruction chains. The matching CUSIP and date restriction precludes any changes to the reported CUSIPs or execution dates. Such changes produce unmatched change records. I encountered 22 such records in the Primary Period. I left them in the sample because they presumably are the correct records. The corresponding uncorrected records are too few in number in comparison to the other records to have a material impact on the results. Dick-Nielsen (2009 and 2014) also discusses these problems.

For the first half of the Full Year sample, the TRACE report date field (trans_dt) value is missing for all records. This omission complicates the correction problem. I deleted records that clearly were not correctly matched (for example, where the correction appeared before the time of the trade) and applied filters to remove from the study those trades for which transaction costs or trade throughs exceeded 5%. Failures to correctly cancel and correct traders in the first half of the sample will not have a material impact on the results because I did not use this part of the sample to measure transaction costs, trade through rates, or trade through values. Instead, I estimated these values for this part of the sample using results from the Primary Period analyses. Failures to include, exclude, or correct a relatively small number of records will not materially impact these results.

[11] The TRACE® Reporting and Quotation Service OTC Corporate Bonds and Agency Debt USER GUIDE lists market hours on page 19 (http://www.finra.org/sites/default/files/1TRAQS-CA-UserGuidev4.4.pdf). Actual trade frequencies start rising significantly after 7:15 AM. During the year ended March 31, 2015, in the five 15-minute intervals starting at 8:00 AM through 9:00 AM, trade frequencies are respectively at 20%, 26%, 32%, 40% and 49% of their average 9:00 AM to 5:00PM rate. The frequency rises to a morning high of 126% in the interval starting at 11:00 AM, falls to post lunchtime low of 97% in the 1:15 PM interval, and then rises to an afternoon high of 143% in the 3:00 PM interval after which it tapers off, especially after 4:00 PM. Trade frequencies in the 4:45 PM and 5:00 PM intervals are at 36% and 14% of their average 9:00 AM to 5:00 PM rate.

[12] These filters also exclude trades reported after the early 1:00 PM market close on Christmas Eve and on the day after Thanksgiving. (The latter day is not in the Prime Sample, but it appears in the Full Year sample.) Most of the excluded trades occurred after or before normal trading hours on normal trading days. The few excluded trades with Sunday and holiday reported execution dates probably are early morning trades arranged by US broker-dealers in Asia. Oddly, original trade reports for 189 trades in the year ended March 31, 2015 have reported trade times that are greater than 24:00 hours, the greatest of which is 59:22. All of these trades were in the interval between April 1 and June 30, 2014. If these times were not corrected in subsequent TRACE records, I excluded these trades from the sample. Most of these trades occurred on regular trading days.

deviation from the normal market is expected; and trades with missing CUSIPs (very few trades).[13] These filters collectively eliminate 0.26% of the normal trading hour original trades, 0.06% of the CUSIPs and 0.06% of the CUSIP-days.

Finally, this study examines only bond trades on days for which the minimum trade price is 10 (percentage points of 100) or above. This price filter excludes 0.73% of the remaining trades, 3.47% of the CUSIPs and 1.28% of the CUSIP-days. The final Primary Period sample includes 3,024,971 regular trade reports in 22,923 CUSIPs on 499,437 CUSIP-days spread over 73 market trading days. In total, the filters remove 4.1% of the original trade records. The most common removals are due to trades occurring out of normal trading hours (1.8%) and to cancelled trades (1.4%).

4.2 Best Bids and Offers from Interactive Brokers

Interactive Brokers serves as an agency-only broker for its clients. To facilitate their bond trades, IB collects pre-trade quotes and indications from several electronic trading platforms that offer automated execution services. These bond market centers include BondDesk, BONDLARGE, Knight BondPoint, NYSE Arca Bonds, and Tradeweb, and a few other centers that specialize only in municipal bonds or treasuries.[14] None of these platforms provides universal coverage of all bonds that trade in the U.S. corporate bond markets. IB presents the quoted prices and sizes to its customers in real-time just as it and other brokers do for stocks, options, and futures.

IB retains a continuous record of the best bids and offers (and associated sizes) of which it is aware to support its compliance functions. IB adjusts these bids and offers by any fees that trading on a given platform may entail. For example, if a platform charges 0.01/bond to trade on that platform, IB will record a 100 bid as 99.99 and a 101 offer as 100.01. These net price adjustments reduce the number of trade throughs that I would otherwise find.

IB aggregates size across platforms at the same price. If two platforms both have orders or indications with net bid prices of 100 to buy, IB records the total size of the two bids.

IB provided me with these records for the period spanning December 15, 2014 to April 15, 2015. During this period, IB increased the number of platforms from which it collected data. Quotation activity on these platforms also increased. Accordingly the numbers of records per day and the numbers of different bonds quoted per day increase over the period. I did not use data from April 2015 because TRACE data for this month were not available to me when I conducted this study.

The full Primary Period sample includes 464,352,538 regular quote reports in 17,255 CUSIPs that appear at least once in the TRACE data between 2002 and March 2015. These quotes occur on 871,203 CUSIP-

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[13] Trade reports with missing CUSIPs generally report bond symbols. Bond symbols always map to the same CUSIP (but sometimes the same CUSIP is associated with multiple bond symbols). I use the symbol to assign CUSIPs to TRACE records with missing CUSIPs if the symbol maps to that CUSIP in another record. This procedure appears to correctly assign CUSIPs for corrected or cancelled trades for which the record of the change points to the original trade, but one record has a missing CUSIP.

[14] The list of these platforms appears at https://www.interactivebrokers.com/en/index.php?f=products&p=bond.

days spread over 73 market trading days. Since TRACE trades only occur on 499,437 CUSIP-days, the IB BBO sample includes quotes for many bonds that did not trade on a given day.

IB reported to me that during the week ended September 10, 2015, they obtained complete fills for about 83% of its customers' marketable orders and that they did not receive any cancellations after filling. This statistic indicates that a substantial fraction of the quoted and indicated prices that IB records are actionable.

4.3 The TRACE and IB BBO Subsets

Many records appear in the IB data when no trade reports appear in TRACE. Quotes on these days provide no information relevant to the question of how often trade throughs occur. Likewise, trades occur in many bonds on days for which no orders or indications appear in the IB quote data. Trades on those days also provide no information relevant to this question.

I subset the IB quote data to include only quotes for corporate bonds on days for which TRACE reports a trade in that bond on that day during the Prime Period. I likewise subset the TRACE data to include only trades for bonds on days for which IB reports at least one quote in that bond during the Prime Period.

The TRACE subset includes 2,152,113 trades in 14,327 bonds that occur on 332,747 CUSIP-days. These figures represent 71.1% of all trades, 62.5% of all bonds, and 66.6% of all CUSIP-days in the full TRACE data during the Prime Period. The higher percentages of trades and of CUSIP-days in the subset sample than of bonds indicates that IB collects quotes for bonds that on average are more actively traded than those in the entire TRACE universe. This result is due to the fact that more quotes are available for such bonds, but it also may reflect listing decisions made by the venues that supply quotes to IB.

The IB quote subset contains 245,992,852 quotes in the same (by design) numbers of bonds and CUSIP-days. The total quotes in the subset are only 53.0% of the total quotes in the full IB quote data during the Prime Period (which includes all available data from IB). The smaller fraction compared to those presented above reflects the fact that the subset sample does not include bonds for which no trades occurred.

These results indicate that the IB quotes cover a substantial fraction of the TRACE universe. Although the subset sample is clearly subject to a selection bias—it does not contain trades for which IB could not or did not collect quotes, it is still largely representative of more than seven-tenths of all trading in the U.S. corporate bond market during the Prime Period (the second half of December 2015 through March 2015).

4.4 TRACE Trading Activity

Trade Frequencies

Table 8 tabulates the cross-sectional distributions of various variables that characterize trade frequencies in the full TRACE Primary Period data set and in the subset of this data set. As is well known, most corporate bonds do not trade frequently. The median trade rate in the full sample is only 0.34 trades per trading day in the 73 trading-day sample. It is slightly higher (0.56) in the subset data that includes only bond trades on CUSIP-days for which at least one quote was reported to IB.

The distribution of trade rates is highly right skewed: In both samples, 5% of the bonds have more than 8 trades per day and 1% have more than 22 trades per day. Trading in most bonds is also episodic. The median number of trades per day on days when a bond trades is 2.50 in the full sample and 2.76 in the subset. The median percentages of days on which a trade took place in these bonds are respectively 15.1% and 21.9%.

Although most bonds do not trade actively, some do. In the full sample, 570 bonds traded every day (results not tabulated). The mean and median trade rates for these bonds are 21.3 and 16.7 trades per day. The subset sample includes all but 17 of these bonds, all of which traded more than 7 times a day on average. IB reports that the 17 omitted bonds are convertible bonds for which it does not support trading. Thus no quotes for these bonds appear in the IB quote data.

Trade Size

Practitioners and academics often label trades with par values of $100,000 or less as retail-size trades, and larger trades as institutional-size trades. Many trades are relatively small retail-size trades. During the Primary Period, 67.3% of the trades in the full sample are retail-size trades (Table 9). Retail-size trades represent a slightly larger fraction (69.7%) in the subset sample. The median par value size of the retail-size trades is $18,000 in both samples.

The Enhanced TRACE data set provides actual trade sizes for all trades, but with an 18-month lag. During 2012, the last full year for which these data are available to me, the average trade sizes of trades marked 1MM+ and 5MM+ are $6.680M and $29.353M, respectively. In all analyses, I assign the 2002 mean sizes to all these large trades.

The median trade size for institutional-size trades is a little over $500,000 in both samples. The percentages of trades reported with indicators for par value sizes of more than $1,000,000 (speculative grade bonds) and more than $5,000,000 (investment grade bonds) are 4.6% and 1.3% in the full sample and about the same in the subset sample. Assuming that the actual size of these trades is equal to their minimum possible sizes of $1,000,000 and $5,000,000, the truncated mean par value trade size for all institutional-size trades is $908K and $953K in the two samples.

The results in these tables show that the trade size distributions are similar in the two samples. The remainder of this section only presents results for the subset sample. Those for the full sample are similar.

Dealer Sides

Dealers traded with customers in 62.8% of the reported trades (Table 10). Dealers sold to their customers (36.0% of all dealer trades) more often than they bought from them (26.7%), probably because many customers hold bonds until maturity or called. Dealer sales to, and purchases from, customers are more balanced for institutional-size trades (38.0% versus 32.8%, a 5.2%-point difference) than for retail-size trades (35.2% versus 24.1%, a 11.1%-point difference), most probably because many institutions sell bonds as they approach maturity to manage the duration of their portfolios.

The column percentages show that the size distribution of interdealer trades is skewed more toward large trades than are their trades with customers. The difference probably is due to dealers buying a few large blocks to distribute in many trades to retail traders.

Among trades of a given size class, interdealer trades represent the smallest percentage of the largest class—those trades marked 5MM+ (13.1%). Many of these large trades probably are agency trades in which broker-dealers, acting as brokers, intermediate trades between customer buyers and sellers. In contrast, interdealer trades account for 40.8% of retail-size trades. The results in Section 7 show that many of these trades are riskless principal trades.

A flag for commission trades appears in 3.1% of the customer trade reports (results not presented in the tables).[15] The remaining trades are net trades. TRACE requires that the dealer report gross trade prices. The net price to a customer paying a commission is the reported sale price plus or minus the commission. Dealers collected commissions on 3.4% of their sales to customers but only 2.7% of their purchases. The TRACE data that FINRA distributes to the public do not report the actual commissions paid, but FINRA adjusts the trade prices to reflect the commissions so that all prices are on a net basis. The commission collected by those discount broker-dealers that charge commissions is typically $1/bond for a $1,000 bond.[16] Accordingly, if a customer who paid such a commission bought a bond priced at 100, the price reported to the public would be 100.1.

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4.5 IB BBO Quotation Activity

Cross-sectional distributions of various characteristics of the full and subset IB quote datasets appear in Table 11. The median across all bonds of the average number of quote updates received by IB in each bond that appears in TRACE is 116 updates per day in the full sample, and 281 per day in the subset sample that only includes quotes on CUSIP-days with at least one TRACE trade report and at least one IB quote record.[17] The distribution is quite skewed. More than one-quarter of the bonds have more than 885 quote updates per day in the full sample and 1,080 in the subset sample. The cross-sectional means are 492 and 577 updates per day.

The remaining results in this table present cross-sectional distributions of time-weighted averages of various variables that characterize the quotes. For each quote, I compute the time it stood (standing time)

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[15] The flag inexplicably appears in 28 of the 1,086,346 reported interdealer trades, even though the TRACE User manual explicitly states that dealers should only report commissions on customer trades.

[16] For example, discount brokers Schwab, Fidelity, and eTrade charge $1 per bond with minimum commissions of $10, $8, and $10 and maximum commissions of $250, none, and $250. Interactive Brokers, which tends to be a price leader, charges 10 bp ($1) up to $10,000 par value, and 2.5 bp above, with no minimums or maximums. Other brokers are much more expensive. For example, Scottrade changes $35 + $3 per bond. TD Ameritrade and Merrill Edge trade on a net yield basis and thus do not quote commissions. Several brokers note that the offering broker, which may be an affiliate, may separately mark up or mark down the price of the security and thus realize a trading profit on the transaction so that the cost to the customer may include this markup plus a commission.

[17] These averages are based on all 77 trading days in the Primary Period. Note, however, that bonds which were newly issued bonds and or which matured or were called during the sample period could not have traded on every trading day in the period. I did not identify these bonds. As a result, reported daily rates are slightly biased downward. Assuming that a typical bond has a 20-year life and that issuances and retirements are uniformly distributed over all trading days, the expected bias is 77 days ÷ 252 trading days per year ÷ 20 years ÷ 2 × 2 = 1.53% of the reported daily rate. The second to last term reflects the uniform distribution. The last term reflects the fact that bonds are both issued and retired.

until it changed or until the 5:15 PM end of the normal bond trading day.[18] If a quote stood at the normal 8:00 AM market opening time, I compute standing time only from 8:00 AM. If no quote stood at the market opening time, I create a null quote record to account for the standing time between the market open and the first quote. For each bond, I compute standing-time-weighted averages of various variables, and report the cross-sectional distribution in the table.

In the full sample, for the median bonds in their respective distributions, bids and asks were standing during 98.9% and 77.4% of the trading day. In the subset sample which excludes the inactively traded or quoted CUSIP-days, the corresponding rates are 99.2% and 89.5%. These distributions are highly left skewed, especially for ask quotes: In the full sample, bonds at the 10th percentile points have bid and ask quotes standing for only 82.1% and 0.0% of the trading day. The corresponding rates in the subset sample are 78% and 2.3%. The dearth of ask quotes probably reflects the higher costs associated with making market from short positions. To the extent that these quotes represent buy-side trading interest, the paucity of asks may also reflect the limited interest of buy-side institutions in selling the few bonds that they hold in comparison to their potential interest in buying any one of many bonds that may have similar characteristics.

In the full sample, two-sided markets stood for 64.6% of the trading day for the median bond, with 75% of the bonds having two-sided quotes for more than 95.3% of the trading day. The corresponding rates in the subset sample are higher at 81.6% and 97.4%. The average fractions of the trading day for which only one-sided markets were available, or for which no market was available are correspondingly smaller. (The three rates add up to 100 percent.) Note that the sample selection mechanism ensures that these rates are all higher in the subset than would be observed for all bonds on all days.

On average the bonds are priced near par. In both samples, the median standing ask price is 103.1, and the median bid is slightly lower.

In the full sample, for half of the bonds, the average standing spread when a two-sided market is available is less than 135 bp of price. For 10% of the bonds, it is less than 35 bp. The corresponding rates in the subset sample are 126 bp and 34 bp.

Locked and crossed markets are quite rare. They do not appear for most bonds, and they do not stand for long in those bonds where they appear. For more than 75% of the bonds, locked or crossed markets either were not present, or were present for less than 0.005 bp (and thus rounded down to the reported 0.00 bp) of the market session.

I removed from further analyses all quotes for which the bid and ask quote prices cross by more than 5% of their average price as these data probably are erroneous. I left the remaining crossed quotes because they represent real, but very rare, arbitrage opportunities.

[18] The results account for the normal bond trading day end at 1:00 PM EST on the day after Thanksgiving and Christmas Eve.

Finally, the median time-weighted average quoted ask and bid sizes are 138 and 189 bonds in the full sample, and 141 and 190 bonds, in the subset sample. This asymmetry mirrors the asymmetry observed above for quotation frequencies, and is likely due to the same issues.

Overall, these results indicate that electronically accessible bond pre-trade prices are available for a substantial portion of the U.S. corporate bond market. Although corporate bond markets are known for having a huge number of securities, many of which rarely trade and are rarely quoted, a substantial fraction of the market does trade and is actively quoted.

5 Bond Transaction Cost Estimates

5.1 Empirical Methods

The IB BBO data permit direct computation of effective half-spread transaction cost estimates for bond trades when two-sided quotes (or indications) are available.[19] I estimate the cost of trading for the side that initiated the trade by first identifying that side, and then by comparing the trade price to the quote midpoint price.

Comparisons of trades to quotes are most meaningful when the quote was standing long enough that the trade could have been arranged with it. To this end, when measuring transaction costs, I require that the quote stood for at least two seconds before the trade occurred. Since the data are time-stamped only to the second, the two-second difference ensures that the minimum possible time between the quote and the trade is one second, which could occur if the quote posted a moment before the end of a one-second interval, and the trade occurred a moment after the beginning of the interval after the next interval, just slightly more than one second later.

I identify the trade initiator as a buyer if the trade price was above the quote midpoint and as a seller if below. The effective half-spread is the absolute value of the difference between the trade price and quote midpoint, i.e. the price minus the midpoint for identified buyers, and the midpoint price minus the price for identified sellers. If the trade price is exactly at the midpoint, analysts cannot credibly identify the trade initiator, but the effective half-spread is clearly zero for both sides.

Analysts can identify the trade initiator in a one-sided market if the trade is a trade through. For example, if a trade takes place at a price above the asking price, the trade initiator would be the buyer. I use this information when analyzing trade throughs, but not for the transaction cost analyses because the effective half-spread cannot be computed in one-sided markets.

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[19] The effective half spread is half the spread that would have been observed if the quoted bid or offer price associated with the trade were at the trade price and the quoted opposite-side offer or bid price were equally far from the quote midpoint. Two simple arguments motivate its interpretation as a measure of transaction costs. First, assume that the midpoint is our best measure of the value of the bond given the available quotes. For a buyer, the excess of trade price over this measure of value indicates how much more the trader paid in excess of the value received. That excess is due to trading and should be considered the transaction cost. Second, imagine that a trader simultaneously bought and sold the same security at the same time. The total loss on this transaction, which accomplishes nothing but generating transaction costs, would be the purchase price minus the sales price. This sum is exactly the sum of the two estimated half-spreads associated with these trades.

5.2 Results

Two-sided quotes from the IB BBO subset are available for 90.4% of all 2,152,113 trades in its associated TRACE subset (Table 12). Of the remaining trades, 9.3% are associated with one-sided quotes, and 0.3% have no quotes. These transaction-weighted quotation rates are higher than the time-weighted quotation rates reported in Table 11: Not surprisingly, trades occur more often in quoted markets.

Among the one-sided markets, standing bids are more than twice as common (6.3% of all trades) as standing asks (3.1%). This asymmetry may reflect the difficulties associated with borrowing bonds to sell short. Dealers can easily bid to buy bonds that they do not have, but most probably only quote to sell those bonds that they have in inventory, or perhaps that their clients want to sell.

Trades classified as buyer- and seller-initiated respectively account for 55.2% and 36.2% of the trades. I could not assign an initiation side to 0.3% of the trades because their trade prices are exactly equal to their associated quotation midpoints. I do not classify the remaining 8.3% of the trades because they occur in one-sided markets. Recall again that trades for which no quote appears in the IB quote data on that day do not appear in this trade subset.

Only 2.4% of all trades occurred when the opposing-side quote (ask for a buyer-initiated trade, bid otherwise) stood for less than 2 seconds (Table 13). These trades do not appear in any of the following analyses to ensure that the results only reflect trades for which traders clearly could have accessed the standing quotes. This filter also removes the 8.3% of all trades with no standing quotes.

A relatively small number of trades (3,075) representing 0.14% of the sample are at prices that trade through a quote by 5% or more of the trade price (results not reported in tables). My examinations of some of the transaction records suggest that many of these trade prices were erroneous. At least four processes may explain these errors: Dealers did not correct erroneous trade reports; I could not apply the appropriate correction to the trade price (see Footnote 10); dealers chose not to correct small trades that benefited their clients; or dealers provided overly aggressive quotes to IB. The bad quote explanation is unlikely for those markets with two-sided quotes for which the traded through dealer only provided a one-sided quote because the quotes in the IB data very rarely cross (the ask is almost always above the bid)—an overly aggressive bid or offer in such markets would create a crossed market. Instead, for a two-sided market, both quotes would have to be too high or too low to cause a large trade through assuming that the trade price is correct. However, some evidence suggests that problems with the quotes (or at least with dealer valuations) may explain some of these extreme trade throughs: 25.0% of the extreme trade throughs appear in one-sided markets, substantially more than the unconditional fraction of trades in one-sided markets (9.3% reported above). I removed these extreme trade-through trades from further analyses.

The mean relative quoted half-spread (half the quoted spread as a fraction of price) for all trades with two-sided quotes standing for at least two seconds is 43.5 bp (Table 14). The classified means for customer trades and interdealer trades are nearly the same at 43.9 bp and 42.7 bp. Equivalent bid/ask spreads for a \$40 stock would be 34.8¢/share (2×43.5 bp $\times$ \$40).

The effective half-spread measured as a fraction of price for these trades is 55.2 bp. The classified means are 65.7 bp for customer trades, and 39.5 bp for interdealer trades. Interdealer trades probably are cheaper because dealers know more about values than do customers and thus negotiate better prices from their colleagues than do customers from their dealers. They also have better access to the markets. Since the mean effective half-spreads are greater than the mean quoted half-spreads, many of these trades must have traded through the best bid or offer.

Focusing only on customer trades, mean effective half-spread transaction costs are greater for retail-size trades (77.2 bp) than for institutional-size trades (39.4 bp). These results are similar to those reported in other studies. The institutional-size trades probably are cheaper because institutional buy-side traders know more about values than do retail customers and thus negotiate better prices from dealers that do retail traders. They also generally have much better access to the markets than do retail traders. As noted by other authors, these results are surprising because arranging large trades involves more search costs and more potential adverse selection costs than does arranging small trades.

Within the institutional-size customer trades, the most expensive trades are trades with sizes marked 1MM+ (50.7 bp). These trades are exclusively in non-investment grade bonds for which liquidity conditions generally are worse and adverse selection is higher. Trades with sizes reported to be more than \$1M and less than or equal to \$5M (31.2 bp) or marked 5MM+ (30.2 bp) are all exclusively in investment grade bonds, which may explain some of their smaller mean costs. The smallest institutional sized trades between \$100K and \$1M (40.3 bp) are more expensive than the larger ones.

These effective half-spreads are large compared to those typically estimated in the equity markets. For example, the mean retail customer effective half-spread of 77.2 bp is equivalent to a 62¢ quoted spread on a \$40 stock. Actual quoted spreads for such stocks typically now are between 1¢ and 5¢ and rarely as high as 50¢ for even inactively traded stocks. Moreover, retail-size orders rarely trade through them. These bond spreads are comparable to equity spreads that prevailed in NASDAQ stocks before various SEC-, NASD-, and court-mandated order handling rules (and decimalization) caused them to narrow significantly. Before those changes, the NASDAQ markets were dealer markets with a market structure in many respects similar to current bond market structure. This comparison suggests that the imposition of similar order handing rules would produce more liquid bond markets, though not necessarily as liquid as current equity markets because of the larger number of issues.

Differences in risk cannot explain the higher spreads in the corporate bond markets because the risk in equities generally is many times the risk in bonds. Moreover, differences in adverse selection risk cannot explain the result because adverse selection spreads generally increase with trade size.[20]

Average price improvement—the difference between the trade price and the opposing side quoted price—is negative for customer trades because many customer trades trade through the quoted price.[21] The next section presents more results about these trade throughs. The negative price improvement appears in dealer sales to customers and not in purchases from them. These results likely reflect the markups that dealers apply to sales when distributing bonds to customers.

[20] Glosten and Milgrom (1985) introduced adverse selection spreads. Kyle (1985) explains why they should increase with trade size, and Glosten and Harris (1988) provide empirical evidence that they typically do.
[21] Price improvement plus the effective half spread is algebraically equal to the quoted half spread.

To estimate the total transaction costs of the trades in the TRACE subset sample for which two-sided quotes are available, for each trade I multiply the relative effective spread times the market value of the trade ($Price \times ParValue \div 100$) and then sum across all trades. During the Primary Period, these costs total $4.909 billion for customer trades.[22] Actual total transaction costs are higher because many bond trades in TRACE do not appear in the subset sample and because some bonds in the subset sample do not have two-sided quotes or opposing-side quotes that were standing for more than 2 seconds when the trade occurred. Section 9 provides estimates of the total transaction costs for all customer bond trades for the year ending March 31, 2015 using regression methods applied to these transaction cost estimates.

Dealers report that they collected a commission for 2.3% of the 1,179,243 customer trades that occurred in two-sided markets for which the quote was standing for at least 2 seconds (Table 15). These trades were mostly retail-size trades (86.6% of all commission trades whereas retail-size trades are 66.8% of all customer trades). These trades took place in markets where mean quoted half-spreads (52.2 bp) were wider than those trades arranged without commissions (43.6 bp). Mean price improvement for the commission trades (-17.8 bp) was slightly less worse than for the non-commission trades (-20.9 bp), so that customers apparently received some service for their commissions (recall that the prices that FINRA disseminates to the public include the commissions as though they were collected as markups). For a $1,000 par value bond trading at 100, the value of the increased price improvement (3.6 bp = -17.3 – -20.9 bp) is 36¢ per bond.

6 Trade Throughs

6.1 Empirical Methods

To identify trade throughs, I identify all TRACE trades that took place when a bid or offer was reported to be standing. If the trade took place at a price above the best ask, or at a price below the best bid, I identify the trade as a trade through and record the difference between the trade price and the best bid or offer traded through.

To quantify the economic importance of the trade through, I record the minimum of the quoted size and the size of the trade. For customer trades, I then decrement the quotation size by this amount to avoid double-counting size should another trade through occur while the same quote was standing. I do not decrement the quotation size for an interdealer trade that is part of a sequence of trades at the same price if one of these trades is a customer trade to ensure that the available size is associated with the customer trade. This decrementing procedure causes some undercounting to occur when traders hide the full sizes of their orders and refresh them after trades occur. Some double counting undoubtedly occurs when trader cancel and replace an orders that otherwise would have disappeared if they had filled.

[22] This sum is $1.78B when the assumed trade sizes for the large 1MM+ and 5MM+ trades are set to their minimum values of $1M and $5M.

6.2 Results

Using the IB BBO during the 3½ month Primary Period, among the 2,152,113 total trade reports in the associated TRACE subset, I identify 923,515 (42.9%) trade throughs of any standing quote or indication (Table 16).[23] Most (96.8%) of these trade throughs occurred in two-sided markets; 3.2% occurred in one-sided markets. The fact that a price does not trade through a one-sided quote does not mean that it might not have traded through a quote unknown to IB on the other side of the market. I identify the trade through status of all such trades as unknown.

Since the IB quote data do not represent quotes from all sources, additional trade throughs may have occurred in many bonds. Such trade throughs may be in markets for which IB did not collect quotes, for which IB only received a quote on a one side, or for which IB did not receive the best quote. Also, note that since some of the quotes are actually indications that dealers might not honor, the better traded through price may not actually have been available.

These trade throughs almost all (97.6%) occurred when the opposing-side quote (the traded-through quote) was standing for 2 seconds or more (Table 17). As before, I exclude from all further analyses those trades that occurred when the quote was standing for less than 2 seconds and also the 3,075 trades (0.14% of all trades) with prices that trade through a quote by 5% or more of the trade price.

Table 18 presents the distribution of price improvements for all trades for which two-sided quotes were standing for at least 2 seconds. The trade-through rate for these trades is 46.8%. The average price improvement for trade throughs is -52 bp of price. On average, trade throughs take place in narrower markets than do trades priced at the market or trades with improved prices. The mean relative half-spread for trade throughs is 35 bp. For trades priced at the market and with improved prices, these means are respectively 40 bp and 52 bp. However, despite these differences, the trade throughs are still substantially more costly due to their large negative price improvements. The mean transaction cost (relative effective half-spreads) for trade-throughs is 87 bp compared to 40 bp and 26 bp, respectively, for trades priced at the market and with improved prices.

The total transaction cost for trade throughs in the TRACE subset is $2.960B. Of this amount, $155M is the value of the price dis-improvement associated with the trade through ("the trade-through value"), which is computed as the price improvement times the minimum of the trade size and the remaining quotation size. Trade-through value measures the dollar value of the benefit that traders who received inferior prices would have obtained had they traded at the quoted prices. Recall that the TRACE subset does not include bonds on days for which no quote appears in the IB BBO sample. Also recall that some of the quoted prices are actually indications that dealers might not honor. Section 9 provides an estimate of the aggregate trade-through value for all bonds for the Full Year sample.

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[23] This count includes all trade throughs regardless of the size of quote. The economic significance of a large size trade that trades through a small size quote depends on the perspective of the trader. The trade through probably matters more to the trader whose quote was traded through than to the large trader interested in filling a large order. However, in both cases, the economic loss depends on the minimum of the two sizes. These losses are evaluated in subsequent analyses.

Trade throughs with small absolute price improvements of -10 to 0 bp are common (16.3% of all trade throughs) but their contribution to the total trade-through value is only $8M. The results in the remaining analyses exclude these de minimis trade throughs, many of which may be a natural consequence of net trade pricing without commissions.

A cursory examination of these results shows that trade-through trades are about half the size on average than price-improved trades: By coincidence, both types of trades are about equally common (just under 900 thousand in the sample), but the total dollar size of the price-improved trades is almost twice that of the trade throughs.

Most (82.3%) of the customer trade throughs are retail-size trades (Table 19). The mean price improvement for these trades is -93 bp, nearly a 1% markup. These markups seem quite large for relatively easy-to-arrange trades that can be arranged electronically. The total trade-through value for the retail trades is $74M. The mean price dis-improvement is smaller for institutional trades that traded through. Although these institutional trades are much larger, the total trade-through value is relatively small because these trades outsize the quotes. The average ratio of quote size to trade size is only 0.7% for institutional size trades in comparison to 28% for retail-size trades.

Table 20 presents execution quality statistics for trade throughs tabulated by the dealer side and the trade-initiating side (the side that traded through). Almost two-thirds (62.5%) of the non de minimis trade throughs are buyer-initiated trades (at prices above the standing ask) with the remainder seller-initiated (at prices below the standing bid). Mean quoted spreads are almost equal for both types of trades at 40-41 bp, but the buyer-initiated trades have higher average transaction costs (128 bp versus 99 bp) because the degree to which they traded through price is greater (mean price improvement of -87 bp versus -61 bp). Although the total dollar volume is similar for both types of trades at 138B and 168B, the value traded through is disproportionately higher for the buyer-initiated trades ($105M versus $41M) than the mean price improvements would suggest. The reason is due to the smaller sizes of the buyer-initiated trade throughs which are almost twice as numerous than the seller-initiated trade throughs but which have almost the same aggregate size. The larger seller-initiated trade throughs generally are bigger than the bid sizes so that value traded through is often limited by the quotation size and not by the trade size.

Customer trades account for 78.7% of the trade throughs with interdealer trades accounting for the remainder. Dealers selling to customers account for 64.8% (299,205) of the customer trade throughs (461,599) in comparison to only 35.2% for dealers buying from customers. The mean price improvement for all customer trades is -86 bp; for only dealer sales to customers, it is -98 bp; and for interdealer trades it is only -45 bp. The total trade-through value for the customer trade throughs is $131M in comparison to only $15M for the interdealer trade throughs.

Among the trade throughs that involve customers, 93.4% of the dealer purchases from customer sellers are seller-initiated and 95.4% of dealer sales to customer buyers are buyer-initiated. The remainders were dealer-initiated trades. The relatively few dealer-initiated customer trade throughs (5.3% of all customer trade throughs) may be the result of dealers seeking liquidity from institutional buy-side traders. Institutional-size trades represent 66.8% (results not reported in tables) of these trades, which is much larger than the typical trade through, which is a retail-size trade. To some extent, these trades also may be due to data problems.

Many trade throughs may involve riskless principal trades. The next section characterizes riskless principal trades, and Section 8 characterizes those trade throughs that are riskless principal trades.

7 Riskless Principal Trades

7.1 Empirical Methods

I identify potential RPTs as pairs of sequentially adjacent trades of the same size for which one trade is a customer trade. To find these trades in the TRACE data, I first identify all size runs (sequences) of two or more trades of equal size. Next for each size run, I consider which trades, if any, constitute a pair of trades in a potential RPT. I identify potential RPTs if one trade of two adjacent trades within a size run is a dealer trade with a customer, or if both trades in an adjacent pair are customer trades and the dealer both buys and sells. I identify the first such pair as a potential RPT, and then continue searching the size run for any additional pairs that do not involve trades already identified as being part of a potential RPT.

I then classify the potential RPTs so identified by whether both trades in the pair were customer trades ("crossing RPTs") or whether one of the trades was an interdealer trade ("normal RPTs"). For those pairs with an interdealer trade, I further classify the trades by whether the dealer sold to or bought from the customer in the other trade. I also note whether the interdealer trade preceded or followed the customer trade within the pair.

I identify RPTs as those potential RPTs for which the time between the two trades in the pair is 1 minute or less. I further identify as electronic RPTs those potential RPTs for which this time interval is 1 second or less.

7.2 Results

For the full year ending March 31, 2015, among the set of all 9,883,107 TRACE corrected and filtered reports of regular trades in corporate bonds with trade prices over 10, 64.6% are in a size run, 56.8% are in a size run that includes at least one potential RPT pair, and 49.7% are in a potential RPT pair (Table 21). These potential RPT pairs do not include RPTs for which one side or the other involved multiple trades so that the adjacent trades are not of equal size.[24] At 41.3% of all trades, the normal RPTs involving an interdealer trade are almost five times more common than the crossing RPTs (8.5%) that involve two offsetting customer trades.

The remaining analyses in this section counts potential RPT pairs and not the individual trades since the two trades within each pair are identical except for their prices and execution times. The sample includes 4,914,396 trades in 2,457,198 potential RPT pairs.

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[24] Some unidentified RPTs also may appear among the 7.5% of trades in size runs that do not include potential riskless principal trades. Some trades in these runs may be distributions of equal size made to multiple accounts. Alternatively, some of these trades may be algorithmic trades. Also note that some trades not identified as RPTs in size runs that include potential RPTs may also be RPTs that the classification procedure cannot identify. For example, if a dealer reports two dealer trades followed by two customer trades, presumably out of sequence, all of the same size, the classification procedure will only identify one riskless principal trade pair when in fact two may have occurred.

The reported times of trade (recorded only to the second) are exactly the same for 53.0% of the potential RPT pairs, and they are separated by one second or less for 61.0% of these pairs (Table 22). These statistics indicate that the percentage of trades for which the actual elapsed time (counting milliseconds) between trade reports is less than one second is between 53.0% and 61.0%.[25] The same dealers very likely arranged these trades simultaneously, and electronic systems very likely reported these trades.

For 83.9% (2,062,706) of all potential RPT pairs, the reported time between the trades is 1 minute or less. The same dealers likely arranged these trades at nearly the same times. These trades represent 41.7% of all trades (9,883,107 from Table 21). All results that follow only include identified pairs for which the time between trades was 1 minute or less.

All of the above rates are somewhat higher in the Prime Period subset sample (results not shown), which does not include earlier dates from April 1, 2015 to December 14, 2015. This contrast suggests that trading in the bond markets is becoming more electronic.

The difference between the two trade prices in a RPT pair is the markup. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, I identify the markup as the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving a dealer purchase from a customer. I compute the relative markup as the ratio of the markup to the average of the two prices in the pair of trades.

The markup is zero for 45.4% of the RPT pairs with trade reports within one minute of each other (Table 23). Many of these zero-price-difference pairs may be reports of agency trades or of trades arranged for wrap accounts where the broker-dealer does not charge commissions or markups. The fraction of trades reported with zero markups declines with the length of the interval between the two trades. Quick reporting of agency and of wrap trades may explain this result.

To some extent the decline in zero-markup trades with time-between-trades also may indicate that some trade pairs with non-zero markups are not RPTs since the longer the interval between any two non-RPT trades, the greater the probability that they will be arranged at different prices simply due to price volatility or because different dealers arrange the two trades. Fortunately, because trades reported more than 5 seconds apart represent only 18.9% of all potential RPT pairs reported in a minute or less, and because many of these likely are indeed RPTs, the relatively few pairs that are not truly RPTs should not have much influence on the results.

[25] The actual percentage of trades reported within 1 second or less obviously can be no lower than the percentage of trades reported with the same times. It is larger because for some pairs, the first trade may be reported near the end of a one-second interval and while the second trade is reported less than 1 second later in the next one-second interval. An upper bound for the maximum percentage thus is the sum of the percentages of pairs reported 0 and 1 seconds apart.

Among the potential RPTs, 0.3% (6,574) have negative markups. The negative markups are unlikely to be RPTs. Note that the number of trades reported with negative markups rises with the length of the interval between the two trades. Price volatility would explain this result if these trades were not RPTs.

If the process that creates these negative market pairs is symmetric in the computed markup (which is not really a markup because they presumably are not RPTs), this process may also create an approximately equal number of pairs with positive markups that also are unlikely to be RPTs. Since I cannot identify which positive-markup potential RPTs are not RPTs, I keep the negative-markup RPTs in the sample to ensure that results about mean markups are not upward biased (under the assumption that the distribution of computed markups from the non-RPTs in the set of potential RPTs is symmetric about zero). If indeed the positive non-RPTs are 0.3% of all trades in the set of potential RPTs, the other positive-markup RPTs represent 54.0% (= 54.3% – 0.3%) of the potential RPTs.

I eliminated three types of potential RPTs (with time between trades of 1 minute or less) from further analysis:

1. Markups are between -5% and 5% of the average of the two trade prices for 99.979% of the potential RPT pairs (results not in tables). I examined many of the remaining 433 pairs and determined that many of them appear to be the result of trading or report errors that apparently were not corrected.[26] I eliminate these extreme markup pairs from further analysis.
2. I eliminate all zero-difference price pairs from further analyses because they most likely are agency trades.
3. Markups are between -10 and 10 bp for 61.8% (1,294,552) of the potential RPT pairs. I eliminate these de minimis markup pairs from further study because many of these markups may be a natural consequence of net trade pricing without commissions.

The remaining sample has 767,722 potential RPT pairs including 3,152 negative markup pairs and presumably approximately another 3,152 positive markup pairs which would not be RPTs given the symmetry assumption. The reported time between trades for the pairs in the remaining sample is 1 second or less for 61.8% of the pairs (results not in tables).

The average markup in the remaining sample is 76.6 bp of price for all trades and 70.6 bp for trades reported within 1 second of each other (Table 24). The markup rises abruptly after 1 second. It is 70.6 bp and 70.1 bp for 0 and 1 seconds. It jumps to 86.2 bp at 2 seconds and remains above 80 bp for all of the remaining classified time intervals. It appears that RPT trades that are arranged automatically have smaller markups. The larger markups at the longer intervals may be due to price volatility affecting any non-RPTs in this sample, or to dealers pricing trades that may be costlier for them to arrange, and thus take longer.

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[26] The errors were not necessarily reporting errors. For example, I found several customer trades that occurred at extremely large negative markups where it appears that the dealers entered the wrong first digit for the price of a small trade. The reported trade prices could be correct if the dealers decided to give their customers the benefit of these trading mistakes.

The total value of these markups is $602M.[27] The markups occur on customer trades with a reported aggregate market trade value of $185B.

Results in Table 25 show that retail-size trades ($100,000 or less in par value) are a greater fraction of the potential RPTs (90.3%) than they are of all trades (60.4% from Table 4). Mean markups for these trades also are larger than for institutional-size trades at 79.0 bp versus 54.7 bp. Retail traders probably pay markups more often and at higher values because they are less able to negotiate trades than can institutional buy-side traders. Among institutional-size trades, markups and markup values are highest for smaller trades. These results suggest that automated trade systems might most benefit retail traders and small institutional traders. The aggregate markup values for retail-size and institutional-size customer RPT trades are respectively $138M and $464M.

In the RPT pairs, dealers sold to customers more often (58.1%) than they bought from them (36.2%) (Table 26). They intermediated between two customers in the remaining 5.7% of the pairs. The asymmetry between dealer sales and purchases is greatest for the retail-size trades and is much smaller or reversed for larger trades. As noted in the transaction cost results discussion, the asymmetry between purchases and sales probably is due to the propensity of retail traders to hold bonds to maturity. The total markup value on dealer RPT trades with customers is $291M ($115B from sellers and $176B from buyers).

The fraction of RPT pairs in which the dealer intermediated between a customer buyer and a customer seller (and the markup is more than 10 bp) increases substantially with trade size.[28] It is only 2.5% for retail-size trades, but it rises to as high as 82.2% for trades marked 1MM+. This result undoubtedly reflects the difficulty of arranging large trades. Dealers probably cannot easily find other dealers willing to take the other side of a large order. Instead, they search for another customer. The large trades in speculative bonds are quite risky and dealers undoubtedly shy away from committing capital to them. This business is largely an agency brokerage business with compensation coming from markups rather than commissions. The average markup for these dealer-intermediated RPTs is only 49.7 bp for all such trades (24.9 bp per side), and it declines with trade size. Note that the total markup value due to intermediated trades of all sizes is $312M and thus about 51.7% of the total markup value of all RPTs.

Dealers report that they collected a commission in addition to their markup in 9.3% of these RPTs (Table 27). The mean markup is much smaller for the commission trades (31.5 bp) than for the other trades (81.3 bp), and the mean markup on institutional-size commission trades (the vast majority of which are under $1M in size) is smaller at 22.8 bp. For retail-size trades, the difference in markups is 52.6 bp (= 84.3 bp - 31.7 bp), which is $5.26 for a $1,000 par value bond, or about five times the commission charged by typical discount brokers.

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[27] If the de minimis RPTs were added to this total, it would increase by $65M.

[28] The total number of non-zero markup dealer-intermediated crossing RPTs (including those with de minimis markups) is 114,833. Most (70,872) of these pairs have de minimis markups, and of these, 43.5% are retail-size trades.

For the RPT pairs (with 1 minute or less between trades and no de minimis markups) involving an interdealer trade, dealers traded first in 54.6% of the pairs, with little variation by side (Table 28). The percentage is 52.9% for purchases from customers and 55.7% for sales to customers. For more than half of these RPT pairs, dealers thus are ensuring that their trades are indeed riskless.

Put differently, dealers are taking liquidity in front of their clients—some would say front-running—more than half of the time in these trades. This characterization is not fair for those trades for which the dealer collects no commission. When trading net, the markup is the commission. However, unlike commissions, customers do not know the markups that they will pay before they order their trades.

For 68.8% of the crossing RPTs between two customers, dealers reported their purchase from one customer before their sale to another customer. The reporting order for these RFP trades does not matter. The asymmetry undoubtedly is due to the fact that most people more naturally think in terms of transferring a purchase made from a customer seller to a customer buyer rather than of transferring a sale arranged with a customer buyer to a customer seller.

8 Trade Throughs and Riskless Principal Trades

In the TRACE subset, 40.8% of the customer trade throughs are of trades that I identify as RPTs for which the time between trades in the RPT pair is one minute or less (Table 29). The true fraction of the trade throughs that involved marked up RPTs probably is higher due to RPTs that my methods do not identify. Among the identified RPTs, 79.0% have non-zero markups and 8.8% (16,582 ÷ 188,485) are crossing RPTs involving a customer buyer and a customer seller.

For the customer RPTs (as opposed to the crossing RPTs) with non-zero markups, RPT markup and the trade-through price improvement are approximately the same size and of opposite sign (Table 30). The mean markup and the mean price improvement are 80 and -86 bp, respectively, so that the mean of their sum is -6 bp. The median value of the sum is 0 and the standard deviation of the sum is 37 bp, which is less than half of either of the two means. Across all these trades, the correlation coefficient between the RPT markup and the trade-through price improvement is -86.2%.[29] The correlation very likely would be higher if the IB BBO quote data from which the price improvements are computed did not include variance due to different exchange fees.

These results strongly suggest that when dealers arrange customer trades that trade through quotes, they often access those quotes for their own accounts through RPTs. Most of these trades (94.5% — results not reported in tables) are retail-size trades. The trade throughs identified as marked up RPTs were more common for dealer sales to customers (68.0% — results not reported in tables) than for dealer purchases from customers. This asymmetry helps explain the asymmetry in the corresponding price improvements. It probably results because dealers commonly offer to sell bonds to their customers from a set of bonds that they know that they can purchase immediately elsewhere. In contrast, dealers often buy whatever bonds their customers want to sell, regardless of whether they can immediately sell them to others.

[29] The correlation coefficient is slightly larger at -87.1% when the dealer-initiated trade throughs are excluded.

RPT markups and trade-through price improvements are smaller and less correlated for the crossing RPTs. With customers on both sides of the trade, the dealer only need price the trade so that the pricing is acceptable to both sides. Many of these trades do not trade through standing quotes. For those that do, the relation between markup and price improvement need not be strong. The standard deviation of their sum, 74 bp, is higher than the mean markup (41 bp) and the mean price improvement (-56 bp), and the correlation across trades is only -35.6%.

9 Aggregate Transaction Cost Estimates for All Corporate Bonds

The aggregate transaction costs and the aggregate trade-through values provided in sections 5.2 and 6.2 aggregate these quantities for only for bonds that appear in the TRACE subset sample, only on the days when those bonds trade, and only when the necessary two-sided quotes for estimating transaction costs are available or only when a trade through occurred through an available quote. Using regression methods, the analyses in this section use these estimates to project total transaction costs and total trade-through values for all TRACE bond trades during the year ended March 31, 2015.

9.1 Total Annual Transaction Costs

To estimate the total transaction costs for all TRACE customer trades, using all customer TRACE trades with two-sided quotes in the IB BBO data set, I regress the relative effective half-spread transaction cost estimate (effective spread expressed as a fraction of the trade price) on a set of regressors computed only using TRACE data. I analyze the relative transaction cost as opposed to the total transaction cost to control for heteroscedasticity in the regression model errors.

The Regression Model

Before discussing the regressors, note that if total transaction cost were a linear function of bond trade size,

$$TransCost = a + bSize$$

relative transaction cost would be given by

$$RelTransCost = \frac{TransCost}{DolSize} = a\frac{1}{DolSize} + b\frac{1}{Price}$$

where $DolSize = Price \times Size$. Likewise, if total transaction cost were a linear function of dollar trade size,

$$TransCost = a + cDolSize$$

relative transaction cost would be given by

$$RelTransCost = a\frac{1}{DolSize} + c$$

In both cases, the fixed cost term a is multiplied by inverse dollar trade size in the relative transaction cost expression. In the first specification, the trade size slope coefficient b is multiplied by inverse price in the relative transaction cost expression. In the second specification, the dollar trade size coefficient appears as a constant.

The regressors are:

Trade-size regressors

InvDollarSize	Inverse of the par value size of the trade. This regressor will identify a fixed cost component, if any, to bond transaction costs in the regression using relative effective spreads as the dependent variable.
InvPrice	Inverse of the trade price. This regressor will identify the linear slope coefficient of trade size as a determinant of total transaction costs in the regression using relative effective spreads as the dependent variable. Since the total costs of large trades increase with trade size, this coefficient should be positive.
TradeSize	Size of the trade in number of bonds (par value size ÷ 1000) with size set to 6,707 and 30,179 bonds for trades reported to be above \$1M and \$5M in par value (the averages sizes of such trades in 2012). This regressor will identify how relative transaction costs depend on size. Previous studies and the evidence tabulated in this study suggest that the coefficient will be negative.
InvtGradeTradeSize	Size of the trade in number of bonds for investment grade bonds, zero otherwise. The relation between size and cost should be weaker for investment grade bonds than for speculative grade bonds.
LargeInvtGrade	An indicator for bond trades with reported par value size of more than \$1M. These investment grade bonds should be cheaper to trade because they are less risky than the average bond in the sample, which includes speculative bonds.
LargeSpecGrade *LargeInvtGrade*	Indicators for whether the bond trade is marked as over \$1M or \$5M in par value. These bonds may be more or less expensive to trade than the assumed constant sizes that I assigned to them would indicate.

Dealer characteristic regressors

DealerSide	Indicator for whether the dealer sold to the customer. The tabular evidence suggests that dealer sales to customers are more expensive than dealer purchases.
CommissionTrade	Indicator for whether the dealer collected a commission on the trade. The cost of commission trades may be different from that of net trades even though the reported trade includes the commission. The tabular evidence suggest that commission trades are cheaper.

Riskless principal trade regressors

NormalMarkupBP	RPT markup in basis points if the trade was part of a normal RPT and zero otherwise. Markup should be a significant determinant of transaction cost.
CrossingMarkupBP	RPT markup in basis points if the trade was a part of a crossing RPT, zero otherwise. Crossing RPTs should be cheaper than other trades.
ZeroMarkup	Indicator for whether the markup is zero for a RPT (likely agency trade). Agency trades and trades for wrap should be cheaper.
Electronic	Indicator for whether the time between the trades in a RPT is 2 seconds or less,

	zero otherwise. The tabular evidence suggests that electronic RPTs are more expensive despite their obviously low marginal cost.

Trade context regressor

AbsTransRet	Absolute price return in basis points from the previous trade (0 if the previous trade was on a different day). The transaction return can identify bid/ask bounce, which contributes to transaction costs.[30]

Liquidity proxy regressors

LogTotalDaysTraded *LogTotalTrades*	The total number of days the bond traded during the year and the total number of TRACE trades during the year. Included as general measures of bond liquidity. Frequently traded bonds should have lower transaction costs.
LogTotalTradesOnDay	The total number of trades in the bond on the day of the trade. Included as a current measure of bond liquidity. Frequently traded bonds should have lower transaction costs.

Bond characteristic regressors

InvtGrade	Indicator for investment grade bonds. These bonds generally are less risky than speculative grade bonds thus should be cheaper to trade.
LongTerm	Indicator for long-term bonds maturating more than 10 years after January 1, 2015. These bonds generally are riskier than mid-term bonds and thus should be more expensive to trade.
ShortTerm	Indicator for short term bonds maturing less than 2 years after January 1, 2015. These bonds generally are less risky than mid-term bonds and thus should be cheaper to trade.
HighRate	Indicator for bonds with coupon rates above 6%. These bonds generally are more risky than mid-rate bonds and thus should be more expensive to trade.
LowRate	Indicator for bonds with coupon rates below 2%. These bonds generally are less risky than mid-rate bonds and thus should be cheaper to trade.
Floating	Indicator for floating rate bonds. These bonds generally are less risky than other fixed rate bonds and thus should be cheaper to trade.
LogPrice	Log bond price. Low price bonds have substantial credit risk and thus should be more expensive to trade.
AverageTradeSize	Average trade size in bonds (par value size ÷ 1,000) during the year. Large trades tend to indicate institutional interest and may be associated with lower transaction costs.

I estimate the regression using all filtered TRACE customer trades in the Primary Period subset sample for which the time since quote is 2 seconds or more. I remove from this sample all trades with suspected bad data that I also remove from the analyses discussed above. These removed trades include trades with prices that trade through a quote by 5% or more of the trade price, and trades which for which trade-

[30] Roll (1984), among many others, discusses price changes and their relation to bid/ask spreads.

through value is more than 5% in absolute value.[31] Although I exclude de minimis trade throughs from other analyses, I do not remove them from the regression sample because they are good trades. Finally, I remove all trades from the regression sample and also the Full Year sample if the calculated RPT markup is greater than 5%. These trades probably involve bad data, most likely either uncorrected TRACE trade reports, or corrections that I could not apply due to limitations in the TRACE data (see Footnote 10). The regression sample includes 1,177,773 trades.

9.1.1 Regression Results

The estimation results appear in Table 31. All but one of the estimated coefficients are statistically significant at any reasonable level of significance, which is not surprising because the specification is based on strong prior information and previous statistical results, and also because the sample size is so large. The one exception, *Floating*, is closely correlated with *LowRate* and thus subject to the multicolinearity problem.

Among the trade size regressors, the negative estimated coefficient for *InvDollarSize* is somewhat unexpected. This regressor identifies a fixed cost component, if any, to bond transaction costs in this regression using relative effective spreads as the dependent variable. A literal interpretation of the coefficient suggests that the fixed cost per transaction of trading bonds is $-0.89 per trade, which is small relative to the total costs associated with most trades. The variable is inversely correlated with *TradeSize* so that the multicolinearity problem may explain the result.

The *InvPrice* coefficient measures the linear slope coefficient of trade size as a determinant of total transaction costs. It is positive as expected and statistically significant.

The *TradeSize* coefficient is negative as expected. At -0.069, the estimated coefficient implies that a 1,000-bond increase in trade size, which would make a retail-size trade into a large institutional-size trade, would reduce the relative transaction cost for the whole trade by 69 bp.

The *InvtGradeTradeSize* coefficient is positive, and at 0.063, is nearly equal in absolute value to the *TradeSize* coefficient. The small difference between the two coefficients indicates that trade size is a much less important determent of relative transaction cost for investment grade bonds than for speculative bonds, probably because values for the former are better known to buy-side traders.

The *LargeSpecGrade* and *LargeInvtGrade* coefficients are positive and statistically significant. These very large trades apparently are more expensive than their assumed sizes would indicate. The *Large InvtGrade* coefficient reflects the fact that *InvtGradeTradeSize* also contributes to the predicted value for these large trades.

Estimated coefficients for the two dealer characteristic regressors, *DealerSide*, the indicator for whether the dealer sold to the customer, and *CommissionTrade*, the indicator for whether the dealer collected a commission on the trade, both have signs expected from the tabulated results. The negative

[31] A trade can pass the first filter but not the second if the market is crossed. I eliminated from all analyses all quotes for which the bid and ask quote prices cross by more than 5%.

CommissionTrade coefficient suggests that brokers obtain better prices when acting as agents for their clients. Although the *t*-statistic for the *CommissionTrade* coefficient is -15, it is among the smaller ones in this regression. Given the enormous sample size, it should not be taken too seriously.

Among the riskless principal trade regressors, *NormalMarkupBP*, the markup in basis points on identified normal RPTs (those involving an interdealer trade), is overwhelmingly statistically significant. Much of the explanatory power in the model comes from this variable. The estimated coefficient at 0.90 indicates that normal markups translate almost 1:1 into transaction costs.

The *CrossingMarkupBP* coefficient is positive and highly significant. The estimate coefficient of 0.406 indicates that these dealer-intermediated agency trades have less impact on relative transaction cost than do trades facilitated by dealers.

The *ZeroMarkup* coefficient is unexpectedly positive and highly significant. If these trades are reports of agency trades or of trades arranged for wrap accounts where the broker-dealer does not charge commissions or markups, as suspected, they are more expensive than the customers involved may recognize. Dealers or their affiliates may markup these trades in earlier transactions before they distribute bonds to their clients.

The *Electronic* coefficient is unexpectedly positive and statistically significant. The tabular evidence in Table 24 suggests that these RPTs, for which the time between trades in the pair is less than 1 second or less, are less expensive. After controlling for the other covariates, they apparently are more expensive despite the fact that the marginal cost of electronic executions is low. Electronic trades may be more expensive because brokers do not negotiate for better prices on these trades.

The estimated coefficient for the trade context regressor, *AbsTransRet*, is positive as expected and significant, though not especially so. This variable, which increases with bid/ask bounce, helps explain transaction costs.

All three of the liquidity proxy variables, *LogTotalDaysTraded*, *LogTotalTrades*, and *LogTotalTradesOnDay* have negative coefficient estimates, as expected. This result is somewhat surprising because the three variables are highly correlated (they all measure liquidity) and thus subject to the multicolinearity problem.

The estimated coefficients for all of the bond characteristic regressors except *Floating* (noted above) have their expected signs and are highly statistically significant. Investment grade bonds, low-coupon rate bonds and short-term bonds have lower transaction costs than speculative bonds, mid-coupon rate bonds, and mid-term bonds. High coupon-rate bonds and long-term bonds likewise have higher transaction costs. The marginal effects of all these range between 17 bp and 37 bp in absolute value. Finally, transaction costs are high for low price bonds in comparison to high price bonds, and they are lower in bonds for which the average trade size is high.

9.1.2 The Full Year Projections

I use these estimation results to predict relative transaction costs for all TRACE trades in the full year ending March 31, 2015. Multiplying these predictions by the market values of the trades, and summing over all TRACE customer trades produces an estimate of $23.6 billion for the total customer transaction costs associated with regular corporate bonds trades with trade prices over $10 in the U.S. markets for the year ending March 31, 2015. Estimated costs would be somewhat higher if the bond trades excluded from the sample were included.

The total predicted transaction costs include \$56M from trades in the Primary Period for which no two-sided quotes were standing at the time of the trade on CUSIP-days in the subset sample, \$22M from trades in the Primary Period from trades on CUSIP-days did not appear in the subset sample because no quotes were reported to IB on that day, \$569M from trades in the Primary Period for which two-sided quotes were standing for one second or less (and to a much lesser extent, from trades not included in the regression because of bad data concerns), and \$18.9B from trades on days in the Full Year sample that were not in the Primary Period sample.

Given the very large number of trades available, I also estimate a much larger regression model to obtain a more precise estimate of the total transaction costs for the year. In this model, I interact all the above variables with an indicator for retail trades (versus institutional trades) crossed with an indicator for dealer sales to customers (versus purchases from buyers) crossed with indicators for the five types of trades that I classify in the RPT analysis (normal RPT trades, crossing RPT trades, not RPT trades in size-run episodes with one or more RPT trades, trades in size-runs that do not have an RPT trade, and trades not in a size-run) so that I effectively estimate 20 (= 2 size levels × 2 dealer side levels × 5 trade classification levels) regressions. Type III *F*-statistics for each of these variables in the model appear in Table 31. They all are highly significant except for *LargeSpecGrade* and *LargeInvtGrade*.[32] Both of these indicator variables have low significance because they are highly correlated with *Retail* and thus effectively serve as secondary intercepts for interactions involving the larger trades (and both have zero values for interactions involving the retail-size trade). The R^2 of the regression rises to 50.3% from 40.4% for the simple model. The interaction model produces an estimate of \$26.0B for the total customer transaction costs, which is somewhat greater than the sum predicted by the simple model. The better fit of this regression with such a large sample suggests that the interactive model estimate may be the better estimate.

The total predicted cost for the in-sample trades is slightly different from the total measured transaction cost. The difference is due to the estimation of a model for relative transaction costs instead of for dollar transaction costs, and it is exactly equal to the summed product of the regression residuals times the market value size of the in-sample trades. (The latter divides transaction cost to obtain relative transaction cost.) Had I estimated a model for dollar transaction costs that includes an intercept, the two totals would be exactly the same. The predicted total for the in-sample trades is 0.67% smaller than the actual total for the simple regression. It is 0.33 smaller for the interaction regression. The smaller number for the interaction regression further suggests that the predicted total from this model is the better estimate.

If for each regression, the summed product of the regression residuals times the trade market values is a constant fraction of the total predicted transaction costs, the best unbiased estimate of the total transaction

[32] Both indicator variables have low significance because they are highly correlated with *Retail* and thus effectively serve as secondary intercepts for interactions involving the larger trades. Both variables also have zero values for all interactions involving retail-size trades.

costs is the predicted transaction cost divided by one minus the in-sample shortfall rate. Applying this correction to the predictions yields $23.7B for the predicted customer costs estimated from the simple regression, and $26.1B for the predicted costs estimated from the interaction regression. This last figure is the best estimate of the total transaction costs.

Discussion

This estimate is very sensitive to the trade sizes assumed for the 1MM+ and 5MM+ trades for which TRACE does not report full trade sizes. I assume that these sizes are equal to their average sizes in the 2012 sample. If instead the sizes are set be equal to their $1M and $5M minimum possible values, the costs would be vastly underestimated. Under this unrealistic assumption, the simple model estimates annual costs of $8.9B and the interaction model estimates annual costs of $9.6B. These are extreme lower bounds for the costs, which are equally likely to be above $26.1B as below.

A simple calculation suggests that these estimates are not unreasonable. The total estimated customer transaction cost in the Primary Period subset sample is $4.9B, and the total customer volumes in the Full Year and in the Primary Period are respectively $7.50T and $2.36T. If transaction costs during the Full Year accrue at the same rate in proportion to total volumes as they do in the Primary Period, they would total $7.50T ÷ $2.36T × $4.9B = $15.6B. This figure is lower than the regression model estimates because the subset total does not include trades for which two-sided quotes were not available, trades in bonds for which IB did not collect quotes, and trades for which the quote was not standing at least 2 seconds before the trade.

Also note that the regression model uses transaction costs estimated from bonds trading in two-sided markets to predict costs for bond trades that did not occur in two-sided markets. The latter are undoubtedly more expensive, but the model cannot estimate these differences. At best, the model only estimates these differences to the extent that they are correlated with the cross-sectional bond characteristic variables such as coupon rate or time to maturity. Even so, the parameter estimates for these variables still reflect liquidity conditions only when two-sided markets were available in these illiquid bonds, at which times trades undoubtedly are cheaper than they would be in one-sided, or no-sided, markets. Accordingly, the $25.8B estimate for total customer transaction costs is very likely low.

Finally note that these estimates do not include exchange fees that some customers may pay.

9.2 Total Annual Trade-through Value

The same OLS regression methods will not produce reliable predictions for total trade-through values because trade-though value is truncated at zero. Instead, Tobit regression methods must be used.

Since trade-through values are limited by the quotation sizes, trade size is not an important determinant of trade-through value for institutional-size trades. Accordingly, heteroscedasticity is not as serious a problem as it is for the total transaction cost estimation problem. These observations suggest that the Tobin model is best estimated for trade-through values and not relative trade-through values, and that the trade size regressor should include size only for retail-size trades with a dummy variable indicating institutional-size trades.

With these changes, I estimated the model using most of the same regressors used in the transaction cost model. Since Tobit regressions must be estimated with nonlinear methods, estimation is particularly sensitive to the multicolinearity problem. To ensure that the optimization process would converge, I omitted various variables that encode essentially the same information as do other variables: *AverageTradeSize* which is closely correlated with the institutional indicator; *LogTotalDaysTraded* and *LogTotalTradesOnDay* which are closely correlated with *LogTotalTrades*; and *Floating* which is closely correlated with *LowRate*.

The coefficient estimates are similar to those obtained for the transaction cost model (results not reported), except that commission trades are associated with smaller relative trade-through values (as shown in Table 27 and discussed above), whereas they are associated with larger relative transaction costs. As before, I estimate both the sample model and the interacted model.[33] The total expected (expected and not predicted in the Tobin model) trade-through values for all TRACE customer trades for the year ending March 31, 2015 are $1,108MM from the simple model and $959M from the interacted model.

Both models substantially overestimate the actual total trade-through value for the in-sample trades, by 41.1% for the simple model and 17.3% for interaction model. The overestimation occurs because the model must fit both the probability of a positive value and also its value if positive. The problem appears to be due to the larger trades for which trade-through values are disproportionately small. Reducing the total expected values by these amounts produces total expected values of $785M from the simple model and $818M from the interaction model.

Although OLS in not appropriate, with the inclusion of an intercept, it has the benefit of ensuring that the total in-sample predicted and actual values are exactly equal. The OLS estimates of the two models produce estimates of $716M and $734M, in line with the adjusted estimates from the Tobit models. As before, the interacted model produces a substantially better fit than does the simple model (R^2 of 7.4% versus 12.9%).[34]

The estimates from both methods are too high because they project trade throughs for bonds that did not have standing quotes when they traded based on rates from bonds that did have quotes standing. A simple grossing up of the subset estimate of $131M (from Table 20) to the full sample based on their different total customer trading volumes is not subject to this criticism. The resulting estimate, $416M (= $7.50T ÷ $2.36T × $131M) is low because of trade throughs that occurred when quotes were standing for less than 2 seconds. Many of these trades could have accessed these quotes electronically, or perhaps accessed earlier standing quotes that I did not analyze.

[33] Issues associated with non-linear optimization make the interacted model too large to estimate in a single regression. Instead, I estimate the model separately for each of the 20 interacted classes while omitting those variables which have zero or constant values for every trade in the class.

[34] The R^2 values are smaller for these trade-through value models than for the transaction cost models due to heteroscedasticity in the dependent variable. The R^2 values are much larger for regressions of relative trade-through values. These regressions are not useful for this analysis because the transformation from relative to absolute values introduces a huge amount of noise for the largest trades.

These various results taken together suggest that total trade-through value for the year ended March 31, 2015 was certainly above $416M and probably below $725M, and in any event, near one-half billion dollars.

10 Summary and Policy Implications

The empirical results show that bond markets are increasingly electronic. Collectively, the market centers from which IB collects electronically accessible quotes have two-sided markets during 65% of the normal trading day for the median bond and at least a one-sided market for 99.6% of the trading day. Continuous two-sided quotations are almost always available for more than 850 of the most actively traded bonds (Table 11).

Some of these quotes are actually indications which dealers might not honor. However, since IB indicates that 83% of its customers' marketable orders fill completely, clearly a very significant fraction of the quotes and indications are actionable.

Public investors may not be obtaining as much benefit as they might from innovative trading systems. When filling their orders, dealers regularly trade through electronically accessible quoted prices at the many venues from which IB collects pre-trade prices. The trade through rate for TRACE trades in two-sided markets standing for at least two seconds is 46.8%. Many of these trades are clearly RPTs where the dealer accesses electronic markets when trading with their clients.

In markets that trade net as opposed to with added on commissions, markups play the role of commissions. Accordingly, trade throughs with modest markups should be quite common. A 10 bp markup over a standing quote is $1 per $1,000 bond, which is the typical commission discount brokers charge to trade bonds. Most customer trade throughs are much larger. Customer trade throughs of more than 10 bp account for 34% (461,600 from Table 19) of all customer orders (1,350,536 from Table 10) and they have an average markup over the standing quote of 36 bp. The trade through rate is higher when trade throughs for which the quote was standing for less than 2 seconds are included.

Broker-dealer costs may explain these larger markups, but for trades arranged electronically, these costs cannot be much different from those associated with processing equities. A 10 bp markup on a 50-bond trade with a principal value of $50,000 generates $50 for the broker-dealer. If in addition, the customer pays a discount commission of just $1/bond, as many do, the total revenue to the broker is $100. These sums are much more than customers typically pay their brokers to arrange a $50,000 stock trade. Finally, note that if the broker receives payments-for-order for routing orders to brokers, these payments further increase the revenues associated with filling customer orders. And note further that these sums do not include transaction costs that the customer incurs when buying at the offer (or higher) or selling at the bid (or lower).

Unlike commissions, retail and many institutional customers generally are not aware of these markups nor are they aware of the payments-for-order-flow that their brokers often receive. Accordingly, brokers do not compete to attract customers by offering lower markups.

10.1 Public Policy Recommendations

Many reasons explain why transaction costs are higher in bond markets than in stock markets. The most common explanation is that so many different bond issues make matching buyers to sellers difficult. This explanation certainly is true for the inactively traded bonds, but many bonds trade as actively as do small- and some mid-cap stocks, and they would undoubtedly trade much more actively if transaction costs were lower. Customers would benefit if the 850 bonds that are quoted nearly continuously were traded in market structures more similar to equity markets than the current OTC markets.

The collection and immediate dissemination of the National Best Bid and Offer (NBBO) is probably most responsible for the much greater efficiency of equity markets than of bond markets. This pre-trade information provides strong incentives to dealers and other traders to offer good prices. It also allows exchanges and ATSs to attract market orders when traders post liquidity in their facilities.

The bond markets would benefit greatly from having a similar NBBO facility. The large number of bond issues should not be an impediment to creating this facility. The equity options markets disseminate a continuous NBBO for far more securities.

The SEC also should consider enacting a trade through rule for bonds similar to that in Reg NMS (for equities) that would require that broker-dealers access electronically available orders when filling orders for their clients before trading through. The SEC may want to do so before a class-action lawsuit based on common law agency principles effectively imposes a Manning Rule for bonds similar to FINRA Rule 5320 (Prohibition Against Trading Ahead of Customer Orders) for equities.

At the minimum, FINRA or the SEC should require that brokers disclose their markup rates on RPTs on a pre-trade basis as they do with their commission rates.[35] Since the two rates are perfect substitutes for each other, investors would be less confused if one rate were simply set to zero. This brokerage pricing standard would ensure that brokers would compete on the same basis for order flow. Since customers understand commissions much better than they understand markups, simply banning markups on RPTs would be best. Such a ban would have no effect on competition because dealers could always raise their commissions to compensate for their lost markups. Their customers then would know the full cost of the intermediation services that they obtain from their brokers.

Finally, a rule that would require brokers to post limit orders of willing customers to venues (order display facilities) that widely disseminate these prices would help prevent many trade throughs. Many trade throughs undoubtedly happen simply because traders are unaware of better prices. Such a rule likely would substantially increase such offers of liquidity, especially if implemented in conjunction with a trade-through rule. These order display facilities could be existing exchanges and ATSs, or new ones formed for this purpose.

[35] This proposal is superficially similar to a proposed FINRA rule described in FINRA Regulatory Notice 14-52 (Pricing Disclosure in the Fixed Income Markets). The proposal calls for post-trade markup disclosure on trade confirmations for RPTs. The one made here calls for markup disclosure on a pre-trade basis.

If the SEC fails to take these actions, and if no class-action suit is successful, the markets will continue to improve as innovators such as IB continue to capture order flow by creating their own NBBOs. But it may be many years before most customers become sophisticated enough to demand these facilities from their brokers, if they ever do, and some brokers may never offer these facilities, either because their customers are not well enough informed or because their customers suffer various agency problems, including the problems associated with payments for order flow.

With respect to trading, bonds are securities just like equities, only less risky. U.S. corporate and municipal bonds presently trade differently for historic reasons. They need not trade differently in the future. U.S. Treasury bonds and corporate bonds in several well developed countries trade in substantially more transparent markets that do corporate and municipal bonds in the U.S. presently do. The quality of these markets shows that opaque markets are not necessary for fixed income securities.

Biais and Green (2007) show that customer transaction costs used to be lower when U.S. corporate and municipal bonds traded in transparent exchange markets in the first half of the 20^{th} century. Had these issues traded in modern electronic trading systems, transaction costs undoubtedly would have been even lower.

Finally, note that the creation of more liquid markets will benefit issuers as well as customers. Investors are more willing to buy securities in the primary markets when they expect that they can sell them easily at low cost in the secondary markets. Low secondary trading costs thus imply higher bond IPO values, and lower corporate funding costs.

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Table 1

Report types in the TRACE data by date of report in the Primary Period sample. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Report date	Record type	N	Percent of Sample	Percent of record type	Trade date to report date in calendar days	
					Median	Mean
All dates	**All record types**	3,241,342	100.0	100.0	0.0	0.0
	Original trade report	3,155,063	97.3	100.0	0.0	0.0
	Cancel instruction	43,314	1.3	100.0	0.0	0.8
	Correction instruction	42,965	1.3	100.0	0.0	0.8
Report date on trade date	**All record types**					
	Original trade report	3,137,060	96.8	**99.4**	0.0	0.0
	Cancel instruction	32,037	1.0	74.0	0.0	0.0
	Correction instruction	32,396	1.0	75.4	0.0	0.0
Report date after trade date	**All record types**	39,849	1.2	100.0	1.0	3.5
	Original trade report	18,003	0.6	0.6	**1.0**	3.8
	Cancel instruction	11,277	0.3	**26.0**	**2.0**	3.1
	Correction instruction	10,569	0.3	**24.6**	**1.0**	3.4

Table 2

Report types by dealer trade type in the Primary Period sample. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

	All Reports		Report Type: Original trade report		Report Type: Cancel instruction		Report Type: Correction instruction	
Dealer trade type	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
All trades	3,241,342	100.0	3,155,063	100.0	43,314	100.0	42,965	100.0
Dealer trade with customer	2,117,374	**65.3**	2,055,312	65.1	33,138	**76.5**	28,924	**67.3**
Dealer bought from customer	934,060	**28.8**	903,144	28.6	17,404	**40.2**	13,512	31.4
Dealer sold to customer	1,183,314	36.5	1,152,168	36.5	15,734	36.3	15,412	35.9
Interdealer trade	1,123,968	34.7	1,099,751	34.9	10,176	23.5	14,041	32.7

Table 3

Two measures of elapsed time from trade execution to trade report by record type for all trades in the Primary Period sample for which the record was reported on the trade date and the trade was not marked as reported late. The TRACE trades are ordered by time of report, but TRACE does not report that time. The lower bound measure is based on the principle that no trade is reported earlier than it occurred. Thus every trade must have been reported no later than the latest reported execution time for all trades that preceded it. The upper bond is based on a similar principle. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Time interval	Report type	N	Mean	Std	Min	Median	Max
Difference between upper and lower report time bounds	**Original trade report**	3,072,909	268	123	0	**246**	14,534
	Cancel instruction	30,294	282	215	3	247	14,534
	Correction instruction	20,722	287	168	5	253	3,419
Elapsed time form execution to earliest possible report time	**Original trade report**	3,072,909	51	**224**	0	**7**	36,062
	Cancel instruction	30,294	2,679	4,699	0	676	35,148
	Correction instruction	20,722	735	3,145	0	195	35,216
Elapsed time from execution to latest possible report time	**Original trade report**	3,072,909	319	**258**	0	**283**	36,601
	Cancel instruction	30,294	2,961	4,740	39	943	36,098
	Correction instruction	20,722	1,021	3,233	15	482	36,273

Table 4

The distribution of elapsed time between trade execution and trade report by trade size for all trades in the Primary Period sample for which the record was reported on the trade date and the trade was not marked as reported late. Trades of more than $1M in speculative grade bonds are marked 1MM+ in the TRACE data base; those more than $5M in investment grade bonds are marked 5MM+. Trades between $1M and $5M are all trades in investment grade bonds. The time intervals are measured relative to the earliest possible report time. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

		Elapsed time between execution and trade report										
		Percent					**Seconds**					
Par value trade size	**N**	**≤10s**	**≤60s**	**≤5m**	**≤15m**	**>15m**	**Mean**	**Median**	**Q3**	**P90**	**P95**	**P99**
All trades	3,072,909	**56.0**	82.3	96.6	100.0	0.0	51	7	35	132	296	597
≤$100K (Retail-size)	2,065,085	**60.4**	87.6	98.0	100.0	0.0	35	**6**	25	81	173	428
>$100K (Institutional-size)	1,007,824	47.1	71.4	93.8	99.9	0.1	82	13	84	296	339	723
$100K< - $1M	676,479	50.5	76.4	95.3	99.9	0.1	68	10	54	270	300	651
Trades marked 1MM+	143,691	39.5	60.1	88.8	99.9	0.1	126	25	177	322	640	740
$1M< - $5M	146,543	42.5	64.4	92.7	100.0	0.0	94	20	120	298	367	715
Trades marked 5MM+	41,111	**34.8**	55.6	89.7	100.0	0.0	118	**41**	157	303	471	744

Table 5

The distribution of elapsed time between trade execution and record change report by report date for all cancel and correction records in the Primary Period sample. The time intervals are measured relative to the earliest possible report time. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

				Elapsed time between execution and record change report						
				Percent					Elapsed time	
Record type	**Report date**	**N**	**%**	**≤10s**	**≤60s**	**≤5m**	**≤15m**	**>15m**	**Median**	**Mean**
Cancel instruction	**All dates**	43,314	100.0	1.4	9.5	23.7	39.3	60.7	2,068s	70,340s
	On trade date	32,037	**74.0**	**1.8**	12.9	32.1	53.1	**46.9**	**765s**	3,101s
	After trade date	11,277	26.0						1.6 days	3.0 days
Correction instruction	**All dates**	42,965	100.0	**2.2**	13.4	30.1	46.9	**53.1**	1,155s	73,605s
	On trade date	32,396	**75.4**	3.0	17.8	39.9	62.2	37.8	**492s**	2,457s
	After trade date	10,569	24.6						1.3 days	3.4 days

Table 6

The distribution of elapsed time between trade execution and original trade report by subsequent change instruction for all customer trades and interdealer trades in the Primary Period sample. The time intervals are measured relative to the earliest possible report time. Customer trades are trades that dealers arranged with customers. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

			Elapsed time between execution and original trade report						
			Percent					Elapsed time	
Reporting Party Side	**Change instruction**	**N**	**≤10s**	**≤60s**	**≤5m**	**≤15m**	**>15m**	**Median**	**Mean**
All	**Never changed**	3,071,919	55.0	80.6	94.6	97.9	2.1	**8**	1,753
	Cancel instruction	43,312	39.8	65.0	80.8	88.2	**11.8**	**20**	13,724
	Correction instruction	39,832	44.7	74.5	90.7	97.0	3.0	**14**	4,131
Customer trade	**Never changed**	1,990,415	51.0	77.4	93.1	97.2	2.8	10	2,317
	Cancel instruction	33,136	39.0	64.7	79.7	87.3	12.7	21	14,495
	Correction instruction	26,616	42.0	71.9	90.3	96.7	3.3	**18**	3,527
Interdealer trade	**Never changed**	1,081,504	62.4	86.5	97.2	99.2	0.8	5	715
	Cancel instruction	10,176	42.4	66.0	84.4	91.2	8.8	19	11,211
	Correction instruction	13,216	49.9	79.9	91.5	97.5	2.5	**11**	5,349

Table 7

Price, size, and execution time corrections to trade records for all final corrected trade records in the Primary Period sample. The unmatched correction records are those for which it was not possible to identify the original trade report due to an index reference problem in the TRACE data. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

		Percent of	Change	
	N	**all corrected trade records**	**Median**	**Mean**
All corrected trade records	39,852	100.0		
All corrected prices	16,252	**40.8**	-0.0%	1.0%
Decrease in price	8,232	20.7	-0.4%	-1.3%
Increase in price	8,020	20.1	0.4%	3.4%
No change in price	23,580	59.2		
Corrected trade sizes				
All corrected sizes	6,962	**17.5**	-0.0%	758.1%
Decrease in size	3,688	9.3	-24.1%	-33.3%
Increase in size	3,274	8.2	33.3%	1,649.5%
No change in size	32,870	82.5		
All corrected execution times	1,099	**2.8**	-1,230s	-3,385s
Decrease in execution time	1,098	2.8	-1,232s	-3,437s
Increase in execution time	**1**	0.0	53,528s	53,528s
No change in execution time	38,733	97.2		
Unmatched correction records	20	0.1		

Table 8

Cross-sectional trade frequency statistics for all filtered bond trades in the full and subset TRACE Primary Period samples. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The full data include all 3,024,971 such trades. The subset data include only those 2,152,113 trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

	Bonds	Mean	Min	Q1	Median	Q3	P90	P95	P99	Max
Panel A: The full sample										
Trades per trading day	22,923	1.81	0.01	0.08	**0.34**	1.48	4.55	**8.11**	**22.01**	211.33
Trades per day traded	22,923	3.87	1.00	2.00	**2.50**	3.63	6.48	10.62	28.34	234.00
Number of days traded	22,923	22	1	3	11	37	64	70	73	73
Fraction of trading days traded	22,923	29.8%	1.4%	4.1%	15.1%	50.7%	87.7%	95.9%	100%	100%
Panel B: The Subset sample										
Trades per trading day	14,327	2.06	0.01	0.16	**0.56**	1.86	5.15	**8.62**	**22.21**	211.33
Trades per day traded	14,327	4.34	1.00	2.00	**2.76**	4.13	7.73	12.43	30.51	211.33
Number of days traded	14,327	23	1	5	16	35	62	70	73	73
Fraction of trading days traded	14,327	31.8%	1.4%	6.8%	21.9%	47.9%	84.9%	95.9%	100%	100%

Table 9

Cross-sectional trade par value size statistics for all filtered bond trades in the full and subset TRACE Primary Period samples. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The full data include all 3,024,971 such trades. The subset data include only those 2,152,113 trades for which at least one quote appears in the IB quote data on the trade date. Trades of more than $1M in speculative grade bonds are marked 1MM+ in the TRACE data base; those more than $5M in investment grade bonds are marked 5MM+. These sizes of these trades are set to their average sizes in the 2012 Enhanced TRACE data set. Trades between $1M and $5M are all trades in investment grade bonds. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

	Full Sample				**Subset Sample**			
Trade par value size	**N**	**%**	**Mean (1,000s)**	**Median (1,000s)**	**N**	**%**	**Mean (1,000s)**	**Median 1(,000s)**
All trades	3,024,971	100.0	352	35	2,152,113	100.0	346	30
≤$100K (Retail-size)	2,035,981	**67.3**	27	**18**	1,500,083	**69.7**	27	**18**
>$100K (Institutional-size)	988,990	32.7	**2,854**	**521**	652,030	30.3	**2,934**	**530**
$100K< - $1M	665,118	22.0	427	300	435,727	20.2	423	300
Trades marked 1MM+	139,047	**4.6**	6,707	6,707	76,285	**3.5**	6,707	6,707
$1M< - $5M	144,299	4.8	2,658	2,175	109,289	5.1	2,653	2,156
Trades marked 5MM+	40,526	**1.3**	30,179	30,179	30,729	**1.4**	30,179	30,179

Table 10

Tabulation of all filtered bond trades in the subset TRACE Primary Period sample. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only 2,152,113 trades for which at least one quote appears in the IB quote data on the trade date. Trades of more than $1M in speculative grade bonds are marked 1MM+ in the TRACE data base; those more than $5M in investment grade bonds are marked 5MM+. Trades between $1M and $5M are all trades in investment grade bonds. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

			Dealer trades with customers			
		All trades	**All trades with customers**	**Dealer bought from customer**	**Dealer sold to customer**	**Interdealer trades**
N	**All trades**	2,152,113	1,350,536	575,529	775,007	801,577
	≤$100K (Retail-size)	1,500,083	888,756	361,396	527,360	611,327
	>$100K (Institutional-size)	652,030	461,780	214,133	247,647	190,250
	$100K< - $1M	435,727	290,396	129,262	161,134	145,331
	Trades marked 1MM+	76,285	63,235	31,944	31,291	13,050
	$1M< - $5M	109,289	81,436	38,768	42,668	27,853
	Trades marked 5MM+	30,729	26,713	14,159	12,554	4,016
Row Percent	**All trades**	100.0	**62.8**	**26.7**	**36.0**	37.2
	≤$100K (Retail-size)	100.0	59.2	**24.1**	**35.2**	**40.8**
	>$100K (Institutional-size)	100.0	70.8	**32.8**	**38.0**	**29.2**
	$100K< - $1M	100.0	66.6	29.7	37.0	**33.4**
	Trades marked 1MM+	100.0	82.9	41.9	41.0	**17.1**
	$1M< - $5M	100.0	74.5	35.5	39.0	**25.5**
	Trades marked 5MM+	100.0	86.9	46.1	40.9	**13.1**
Column Percent	**All trades**	100.0	100.0	100.0	100.0	100.0
	≤$100K (Retail-size)	69.7	**65.8**	62.8	68.0	**76.3**
	>$100K (Institutional-size)	30.3	**34.2**	37.2	32.0	**23.7**
	$100K< - $1M	20.2	**21.5**	22.5	20.8	**18.1**
	Trades marked 1MM+	3.5	**4.7**	5.6	4.0	**1.6**
	$1M< - $5M	5.1	**6.0**	6.7	5.5	**3.5**
	Trades marked 5MM+	1.4	**2.0**	2.5	1.6	**0.5**

Table 11

Cross-sectional distributions of quotation activity statistics for all bond quotes in the full and subset IB quote Primary Period samples. All variables in this table except the first three are time-weighted averages of various quantities. For example, Bid present and Ask present are the fractions of the 8:00 AM to 5:15 trading day that the IB quote data indicate that bids and asks are standing at some electronically accessible market center. The full sample data include all 464,352,538 quotes during the Primary Period in every TRACE bond that appears in the TRACE data between 2002 and March 2015. The subset data include only those 245,992,852 quotes for CUSIP-days for which at least one trade in the bond appears in the filtered TRACE bond trades on the trade date. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Panel A: Full Primary Period data

	N	Mean	P1	P5	P10	Q1	Median	Q3	P90	P95	P99
Total days quoted in sample	17,255	50	2	7	18	27	58	73	73	73	73
Percentage of days in sample	17,255	69.2%	2.7%	9.6%	24.7%	37.0%	79.5%	100%	100%	100%	100%
Average daily quote changes on trade days	17,255	**492**	1	1	2	4	**116**	**885**	1,487	1,737	2,315
Bid present	17,255	92.3%	0.0%	48.7%	**82.1%**	96.0%	**98.9%**	99.8%	99.9%	100%	100%
Ask present	17,255	58.7%	0.0%	0.0%	**0.0%**	5.1%	**77.4%**	97.6%	99.6%	99.9%	100%
Two-sided market	17,255	52.7%	0.0%	0.0%	0.0%	0.9%	**64.6%**	**95.3%**	98.9%	99.6%	100%
One-sided market	17,255	45.6%	0.0%	0.3%	0.9%	4.4%	33.7%	93.8%	98.8%	99.5%	100%
No quote present	17,255	1.7%	0.0%	0.0%	0.0%	0.1%	0.4%	1.6%	4.4%	6.0%	20.8%
Mean best ask	13,831	105.6	57.7	89.1	97.7	100.3	**103.1**	110.3	121.7	131.9	145.5
Mean best bid	16,897	102.4	31.7	83.6	93.0	98.6	**101.0**	107.4	117.0	127.1	141.5
Mean bid/ask spread	13,312	2.47	0.12	0.25	0.36	0.72	1.42	2.82	5.16	7.56	18.41
Mean relative spread (bp)	13,312	260	12	25	**35**	68	**135**	272	502	782	2248
Locked market (bid=ask) frequency (bp)	17,255	2.13	0.00	0.00	0.00	0.00	0.00	**0.00**	0.13	1.88	53.40
Crossed market (bid>ask) frequency (bp)	17,255	1.70	0.00	0.00	0.00	0.00	0.00	**0.00**	0.58	3.10	**30.83**
Mean best ask size (bonds)	13,831	257	3	9	14	39	**138**	297	508	832	1,895
Mean best bid size (bonds)	16,897	304	15	50	75	102	**189**	328	707	1,000	1,764

(Continued)

Table 11, Continued

Panel B: Subset Primary Period data

	N	Mean	P1	P5	P10	Q1	Median	Q3	P90	P95	P99
Total days quoted in sample	14,327	23	1	1	2	5	16	35	62	70	73
Percentage of days in sample	14,327	31.8%	1.4%	1.4%	2.7%	6.8%	21.9%	47.9%	84.9%	95.9%	100%
Average daily quote changes on trade days	14,327	**577**	1	2	3	8	**281**	**1,080**	1,592	1,851	2,430
Bid present	14,327	92.3%	0.0%	45.6%	**80.0%**	96.7%	**99.2%**	99.9%	100%	100%	100%
Ask present	14,327	71.5%	0.0%	0.0%	**2.5%**	50.0%	**89.5%**	98.8%	99.8%	100%	100%
Two-sided market	14,327	65.4%	0.0%	0.0%	0.0%	35.8%	**81.6%**	**97.4%**	99.4%	99.8%	100%
One-sided market	14,327	32.9%	0.0%	0.1%	0.4%	2.3%	17.2%	60.5%	95.5%	99.3%	100%
No quote present	14,327	1.7%	0.0%	0.0%	0.0%	0.0%	0.2%	1.0%	3.6%	7.3%	27.4%
Mean best ask	13,039	106.0	69.5	90.7	98.1	100.3	**103.1**	110.3	121.6	131.5	144.1
Mean best bid	13,995	103.5	64.1	86.1	94.7	99.1	**101.5**	108.1	117.6	127.4	139.9
Mean bid/ask spread	12,613	2.26	0.12	0.24	0.35	0.67	1.33	2.58	4.52	6.20	13.13
Mean relative spread (bp)	12,613	213	12	24	**34**	64	**126**	244	433	608	1465
Locked market (bid=ask) frequency (bp)	14,327	2.94	0.00	0.00	0.00	0.00	0.00	0.00	0.35	3.26	69.21
Crossed market (bid>ask) frequency (bp)	14,327	2.38	0.00	0.00	0.00	0.00	0.00	0.00	1.00	4.62	41.99
Mean best ask size (bonds)	13,039	252	4	10	16	42	**141**	296	500	750	1,800
Mean best bid size (bonds)	13,995	293	15	53	78	107	**190**	307	633	1,000	1,839

Table 12

All filtered TRACE trades in the subset Primary Period sample classified by trade initiator and by presence of quotes in the market standing at the time of the trade. A trade is buyer-initiated if the trade price is above the quote mid-price in a two-sided market or at or above the ask in a one-sided asking market. A trade is seller-initiated if the trade price is below the quote mid-price in a two-sided market or at or below the bid in a one-sided bidding market. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those 2,152,113 trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Trade initiator	**Standing quotes in Market**	**N**	**Percent of all trades**	**Percent of initiating side**
All trade initiators	**All trades**	2,152,113	100.0	
	Two-sided market	1,945,022	**90.4**	
	One-sided market	200,280	**9.3**	
	Standing bid only	134,521	**6.3**	
	Standing ask only	65,759	**3.1**	
	No standing quotes	6,811	**0.3**	
Buyer-initiated	**All buyer-initiated trades**	1,187,850	**55.2**	100.0
	Two-sided market	1,176,570	54.7	99.1
	Standing ask only	11,280	0.5	0.9
Mid-quote trade	**All mid-quote trades (All two-sided)**	7,227	**0.3**	100.0
Seller-initiated	**All seller-initiated trades**	779,305	**36.2**	100.0
	Two-sided market	761,225	35.4	97.7
	Standing bid only	18,080	0.8	2.3
Indeterminate due to incomplete quotes	**All indeterminate trades**	177,731	**8.3**	100.0
	One-sided market	170,920	7.9	96.2
	Standing bid only	116,441	5.4	65.5
	Standing ask only	54,479	2.5	30.7
	No standing quotes	6,811	0.3	3.8

Table 13

Time since last quote update for all filtered TRACE trades in the subset Primary Period sample. The time since last quote update is the elapsed time between the trade and the last ask quote update for buyer-initiated trades, the last bid quote update for seller buyer-initiated trades, and the last update of either quote for trades at the quote midprice. A trade is buyer-initiated if the trade price is above the quote mid-price in a two-sided market or at or above the ask in a one-sided asking market. A trade is seller-initiated if the trade price is below the quote mid-price in a two-sided market or at or below the bid in a one-sided bidding market. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those 2,152,113 trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Time since last quote update	**N**	**%**
All trades	2,152,113	100.0
0s	27,658	1.3
1s	23,159	1.1
2s	20,823	1.0
3-5s	60,475	2.8
6-10s	114,610	5.3
>10s	1,764,566	82.0
Under 2s	50,817	**2.4**
2s or more	1,923,565	89.4
No quote	177,731	**8.3**

Table 14

Transaction costs for all filtered TRACE trades in the Primary Period sample with two-sided quotes that stood for 2 seconds or more before the trade by dealer side and trade size. **Quoted half-spread** is one half the quoted spread standing at the time of the trade. **Effective half spread** is the difference between the trade price and the mid-quote price, signed by whether the trade was buyer- or seller-initiated (trade price above or below the mid-quote price). **Price improvement** is the quoted half-spread minus the effective half-spread. **Total transaction cost** is the summed product of the transaction cost times the trade size for all trades. **Total dollar trade volume** is the summed total market value of all trades. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Trade par value size	**N**	**% of all trades**	**% of size class**	**Mean quoted half-spread (bp of price)**	**Mean effective half-spread (bp of price)**	**Mean price improve-ment (bp of price)**	**Total trans-action cost ($M)**	**Total dollar trade volume ($B)**
All dealer trades								
All trades	1,892,340	100.0	100.0	**43.5**	**55.2**	-11.7	5,738	1,693
$100K (Retail-size)	1,334,028	70.5	100.0	42.2	62.9	-20.7	211	37
>$100K (Institutional-size)	558,312	29.5	100.0	46.5	36.8	9.7	0.8	5,527
$100K< - $1M	373,946	19.8	100.0	45.2	37.3	7.8	1.1	562
Trades marked 1MM+	63,219	3.3	100.0	66.1	48.3	17.8	0.0	1,780
$1M< - $5M	94,816	5.0	100.0	41.2	29.4	11.8	0.2	788
Trades marked 5MM+	26,331	1.4	100.0	38.4	28.8	9.6	0.0	2,396
Dealer trades with customers								
All dealer customer trades	1,179,243	62.3	100.0	**43.9**	**64.7**	-20.8	**4,909**	1,379
$100K (Retail-size)	788,163	41.7	66.8	41.7	**77.2**	-35.5	157	22
>$100K (Institutional-size)	391,080	20.7	33.2	48.2	**39.4**	8.8	0.7	4,753
$100K< - $1M	246,111	13.0	20.9	46.5	**40.3**	6.2	1.1	400
Trades marked 1MM+	52,029	2.7	4.4	68.1	**50.7**	17.5	0.0	1,540
$1M< - $5M	70,139	3.7	5.9	42.4	**31.2**	11.3	0.2	637
Trades marked 5MM+	22,801	1.2	1.9	39.9	**30.2**	9.8	2,175	714

(Continued)

Table 14, Continued

Trade par value size	N	% of all trades	% of size class	Mean quoted half-spread (bp of price)	Mean effective half-spread (bp of price)	Price improve-ment (bp of price)	Total trans-action cost ($M)	Total dollar trade volume ($B)
Dealer purchases from customers								
All dealer purchases	494,627	26.1	100.0	45.4	50.0	-4.6	2,417	700
$100K (Retail-size)	314,721	16.6	63.6	42.9	57.4	-14.5	43	8
>$100K (Institutional-size)	179,906	9.5	36.4	49.9	37.0	12.8	0.6	2,374
$100K< - $1M	108,206	5.7	21.9	48.9	36.6	12.3	0.9	167
Trades marked 1MM+	26,286	1.4	5.3	67.4	50.2	17.2	0.0	769
$1M< - $5M	33,319	1.8	6.7	43.0	30.8	12.3	0.1	302
Trades marked 5MM+	12,095	0.6	2.4	39.3	29.8	9.5	1136	379
Dealer sales to customers								
All dealer sales	684,616	36.2	100.0	42.8	75.3	-32.5	2,493	679
$100K (Retail-size)	473,442	25.0	69.2	41.0	90.4	-49.4	114	14
>$100K (Institutional-size)	211,174	11.2	30.8	46.9	41.5	5.4	0.9	2,379
$100K< - $1M	137,905	7.3	20.1	44.6	43.2	1.4	1.3	234
Trades marked 1MM+	25,743	1.4	3.8	68.9	51.1	17.7	0.0	771
$1M< - $5M	36,820	1.9	5.4	41.9	31.6	10.3	0.2	335
Trades marked 5MM+	10,706	0.6	1.6	40.6	30.5	10.1	1,039	336
Interdealer trades								
All interdealer trades	713,097	37.7	100.0	**42.7**	**39.5**	3.2	829	314
$100K (Retail-size)	545,865	28.8	76.5	42.8	42.2	0.6	55	15
>$100K (Institutional-size)	167,232	8.8	23.5	42.5	30.7	11.8	0.9	774
$100K< - $1M	127,835	6.8	17.9	42.6	31.7	11.0	1.1	162
Trades marked 1MM+	11,190	0.6	1.6	56.7	37.2	19.5	0.0	240
$1M< - $5M	24,677	1.3	3.5	37.6	24.3	13.3	0.2	151
Trades marked 5MM+	3,530	0.2	0.5	28.5	19.8	8.7	221	110

Table 15

Transaction costs for all filtered TRACE dealer trades with customers in the Primary Period sample with two-sided quotes that stood for 2 seconds or more before the trade by commission collected and trade size. **Quoted half-spread** is one half the quoted spread standing at the time of the trade. **Effective half spread** is the difference between the trade price and the mid-quote price, signed by whether the trade was buyer- or seller-initiated (trade price above or below the mid-quote price). **Price improvement** is the quoted half-spread minus the effective half-spread. **Total transaction cost** is the summed product of the transaction cost times the trade size for all trades. **Total dollar trade volume** is the summed total market value of all trades. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Trade par value size	Commission charged	N	% of all trades	% of size class	Mean quoted half-spread (bp of price)	Mean effective half-spread (bp of price)	Mean price improve-ment (bp of price)	Total trans-action cost ($M)	Total dollar trade volume ($B)
	All	1,179,243	100.0	100.0	43.9	64.7	-20.8	4,909	1,379
	No	1,144,548	97.1	100.0	**43.6**	64.5	**-20.9**	4,881	1,372
All	**Yes**	34,695	**2.9**	100.0	**52.2**	69.5	**-17.3**	28	7
$100K (Retail-size)	**No**	758,111	64.3	96.2	41.3	77.3	-36.0	153	22
	Yes	30,052	2.5	3.8	52.1	73.8	-21.7	3	1
>$100K (Institutional-size)	**No**	386,437	32.8	98.8	48.2	39.4	8.8	4,728	1,351
	Yes	4,643	0.4	1.2	52.3	41.4	10.9	24	7
$100K< - $1M	**No**	242,484	20.6	98.5	46.4	40.2	6.1	395	106
	Yes	3,627	0.3	1.5	53.0	41.9	11.0	6	1
Trades marked 1MM+	**No**	51,820	4.4	99.6	68.2	50.7	17.5	1,534	336
	Yes	209	0.0	0.4	52.5	44.8	7.8	6	1
$1M< - $5M	**No**	69,395	5.9	98.9	42.3	31.1	11.2	631	196
	Yes	744	0.1	1.1	50.5	38.8	11.7	6	2
Trades marked 5MM+	**No**	22,738	1.9	99.7	39.9	30.2	9.8	2,169	712
	Yes	63	0.0	0.3	32.9	29.5	3.5	6	2

Table 16

Trade through frequencies for all filtered TRACE trades in the Primary Period sample by number of quotes in the market. A trade through occurs when the trade price is above the ask or below the bid. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

			Trade through						
	All trades		**Yes**			**No**	**Unknown—No quote**		
Standing quotes present	**N**	**% of all trades**	**N**	**% of all trades**	**% of level**	**N**	**N**	**% of all trades**	**% of level**
All trades	2,152,113	100.0	**923,515**	100.0	**42.9**	1,050,867	177,731	100.0	8.3
Two-sided market	1,945,022	90.4	894,155	**96.8**	46.0	1,050,867			
One-sided market	200,280	9.3	29,360	**3.2**	14.7		170,920	96.2	85.3
Standing bid only	134,521	6.3	18,080	2.0	13.4		116,441	65.5	86.6
Standing ask only	65,759	3.1	11,280	1.2	17.2		54,479	30.7	82.8
No standing quotes	6,811	0.3					6,811	3.8	100.0

Table 17

Time since last quote update for all filtered TRACE trade throughs in the subset Primary Period sample. The time since last quote update is the elapsed time between the trade and the last ask quote update for buyer-initiated trades, the last bid quote update for seller buyer-initiated trades, and the last update of either quote for trades at the quote midprice. A trade is buyer-initiated if the trade price is above the quote mid-price in a two-sided market or at or above the ask in a one-sided asking market. A trade is seller-initiated if the trade price is below the quote mid-price in a two-sided market or at or below the bid in a one-sided bidding market. A trade through occurs when the trade price is above the ask or below the bid. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Time since last quote update	N	%
All trade throughs	923,515	100.0
0s	11,655	1.3
1s	10,361	1.1
2s	9,671	1.0
3-5s	27,996	3.0
6-10s	52,681	5.7
>10s	828,068	89.7
Under 2s	22,016	2.4
2s or more	901,499	**97.6**

Table 18

Transaction costs for all filtered TRACE trades in the Primary Period sample with two-sided quotes that stood for 2 seconds or more before the trade, by degree of price improvement. **Quoted half-spread** is one half the quoted spread standing at the time of the trade. **Effective half spread** is the difference between the trade price and the mid-quote price, signed by whether the trade was buyer- or seller-initiated (trade price above or below the mid-quote price). **Price improvement** is the quoted half-spread minus the effective half-spread. **Total transaction cost** is the summed product of the transaction cost times the trade size for all trades. **Total dollar trade volume** is the summed total market value of all trades. **Standing quote to trade size ratio** is the ratio of the opposing side quote size to the trade size. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Degree of price improvement (bp of price)	N	% of all trades	Mean quoted half-spread (bp of price)	Mean effective half-spread (bp of price)	Mean price improvement (bp of price)	Mean standing quote size to trade size ratio (%)	Value traded through ($M)	Total transaction cost ($M)	Total dollar trade volume ($B)
All trades	1,920,509	100.0	43	55	-13	21.2	155	6,738	1,709
Price improved	**865,337**	45.1	**52**	26	26	17.1	n/a	2,626	**1,113**
At market	156,729	8.2	**40**	40	0	24.4	n/a	152	41
Trade through	**898,443**	**46.8**	**35**	87	**-52**	24.7	**155**	**2,960**	**555**
Trade through range									
0 to -10 bp	312,215	**16.3**	25	29	-4	23.9	**8**	621	255
-25 to -10 bp	176,681	9.2	32	48	-16	26.1	16	630	146
-50 to -25 bp	121,082	6.3	39	75	-36	25.5	21	581	81
-100 to -50 bp	119,975	6.2	44	116	-72	25.9	32	534	47
<-100 bp	169,449	8.8	49	222	-173	22.9	77	599	27
<-10 bp	586,307	30.5	41	118	-77	25.0	146	2,339	300

Table 19

Transaction costs for all filtered customer TRACE trade throughs of more than 10 bp in the Primary Period sample with two-sided quotes that stood for 2 seconds or more before the trade by trade size. **Quoted half-spread** is one half the quoted spread standing at the time of the trade. **Effective half spread** is the difference between the trade price and the mid-quote price, signed by whether the trade was buyer- or seller-initiated (trade price above or below the mid-quote price). **Price improvement** is the quoted half-spread minus the effective half-spread. **Total transaction cost** is the summed product of the transaction cost times the trade size for all trades. **Total dollar trade volume** is the summed total market value of all trades. **Standing quote to trade size ratio** is the ratio of the opposing side quote size to the trade size. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

Trade size in par value	N	% of all trades	Mean quoted half-spread (bp of price)	Mean effective half-spread (bp of price)	Mean price improvement (bp of price)	Mean standing quote to trade size ratio (%)	Value traded through ($M)	Total transaction cost ($M)	Total dollar trade volume ($B)
All customer trade throughs	461,600	100.0	41	127	-86	23.1	131	2,082	259
$100K (Retail-size)	380,085	**82.3**	41	134	**-93**	**28.0**	**74**	123	10
>$100K (Institutional-size)	81,515	17.7	41	94	-55	**0.7**	57	1,959	250
$100K< - $1M	54,516	11.8	40	96	-58	1.1	40	182	22
Trades marked 1MM+	11,320	2.5	56	117	-63	0.0	5	694	70
$1M< - $5M	11,742	2.5	35	73	-39	0.1	9	245	34
Trades marked 5MM+	3,937	0.9	33	69	-36	0.0	3	838	124

Table 20

Transaction costs for all filtered TRACE trade throughs of more than 10 bp in the Primary Period sample with two-sided quotes that stood for 2 seconds or more before the trade by initiating side and dealer side. **Quoted half-spread** is one half the quoted spread standing at the time of the trade. **Effective half spread** is the difference between the trade price and the mid-quote price, signed by whether the trade was buyer- or seller-initiated (trade price above or below the mid-quote price). **Price improvement** is the quoted half-spread minus the effective half-spread. **Total transaction cost** is the summed product of the transaction cost times the trade size for all trades. **Total dollar trade volume** is the summed total market value of all trades. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

(Continued)

Table 20, Continued

Dealer side	Initiating side	N	% of all trades	% of dealer trade type	Mean quoted half-spread (bp of price)	Mean effective half-spread (bp of price)	Mean price improvement (bp of price)	Value traded through ($M)	Total transaction cost ($M)	Total dollar trade volume ($B)
All dealer trades	**All trade throughs**	586,243	100.0		41	118	-77	146	2,339	299
	Buyer-initiated	366,628	**62.5**		**41**	**128**	**-87**	**105**	**1,122**	**138**
	Seller-initiated	219,615	**37.5**		**40**	**99**	**-61**	**41**	**1,218**	**164**
Dealer trades with customers	**All**	**461,599**	**78.7**	100.0	41	127	**-86**	**131**	1,082	259
	Buyer-initiated	296,284	50.5	64.2	41	140	-98	97	987	116
	Seller-initiated	165,315	28.2	35.8	40	103	-64	35	1,095	144
Dealer bought from customer	**All**	**162,394**	27.7	100.0	41	104	-64	35	1,017	133
	Buyer-initiated	**10,837**	1.8	6.7	51	102	-53	5	246	27
	Seller-initiated	151,557	25.9	**93.3**	40	104	-65	30	771	106
Dealer sold to customer	**All**	**299,205**	51.0	100.0	41	139	**-98**	96	1,065	126
	Buyer-initiated	285,447	48.7	**95.4**	41	141	-100	92	741	89
	Seller-initiated	**13,758**	2.3	4.6	41	93	-56	4	324	38
Interdealer trades	**All**	124,644	**21.3**	100.0	40	83	-45	**15**	257	40
	Buyer-initiated	70,344	12.0	56.4	41	80	-40	9	135	20
	Seller-initiated	54,300	9.3	43.6	38	87	-51	6	123	20

Table 21

All filtered bond trades in the TRACE Full Year sample classified by position in size-run episodes. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

Trade classification	N	Percent
All trades	**9,883,107**	100.0
All trades in a size-run episode	**6,381,428**	**64.6**
All trades in a size-run episode with a RPT pair	5,613,829	**56.8**
Trades in a RPT pair	4,914,396	**49.7**
Trades in a normal RPT pair	4,078,428	**41.3**
Trades in a crossing RPT pair	835,968	**8.5**
Non-RPT trades in a size-run episode with a RPT pair	699,433	7.1
Trades in a size-run episodes without a RPT pair	767,599	7.8
Trades not in a size-run episode	3,501,679	35.4

Table 22

All potential RPT pairs among all filtered bond trades in the TRACE Full Year sample classified by time between trades in the pair. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

Elapsed time between trades in the RPT pair	**N**	**Percent**
All RPT pairs	2,457,198	100.0
≤1 minute (potential RPT)	**2,062,706**	**83.9**
≤ 1 second (potential electronic RPT)	1,498,270	**61.0**
0s	1,301,576	**53.0**
1s	196,694	8.0
2s	86,404	3.5
3s	41,654	1.7
4s	24,299	1.0
5s	22,443	0.9
6 to 10s	74,534	3.0
11 to 20s	108,304	4.4
21 to 60s	206,798	8.4
1+ to 5 min	173,903	7.1
5+ min	220,589	9.0

Table 23

All potential RPT pairs with time between trades of one minute or less among all filtered bond trades in the TRACE Full Year sample, classified by RPT markup. The RPT markup is the difference between the two trade prices in the pair. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, the markup is the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving a dealer purchase from a customer. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

			RPT markup								
	All RPT Pairs		**Negative**			**Zero**			**Positive**		
Elapsed time between trades in the RPT pair	**N**	**Percent**	**N**	**Column Percent**	**Row Percent**	**N**	**Column Percent**	**Row Percent**	**N**	**Column Percent**	**Row Percent**
≤1 minute (potential RPT)	2,062,706	100.0	**6,574**	100.0	**0.3**	935,777	100.0	**45.4**	1,120,355	100.0	**54.3**
≤ 1 second (potential electronic RPT)	1,498,270	72.6	1,122	17.1	0.1	750,580	80.2	50.1	746,568	66.6	49.8
0s	1,301,576	63.1	**912**	13.9	0.1	685,500	73.3	**52.7**	615,164	54.9	47.3
1s	196,694	9.5	**210**	3.2	0.1	65,080	7.0	**33.1**	131,404	11.7	66.8
2s	86,404	4.2	**159**	2.4	0.2	24,280	2.6	**28.1**	61,965	5.5	71.7
3s	41,654	2.0	**160**	2.4	0.4	13,608	1.5	**32.7**	27,886	2.5	66.9
4s	24,299	1.2	**121**	1.8	0.5	8,939	1.0	**36.8**	15,239	1.4	62.7
5s	22,443	1.1	**147**	2.2	0.7	8,719	0.9	**38.8**	13,577	1.2	60.5
6 to 10s	74,534	**3.6**	**683**	10.4	0.9	29,857	3.2	**40.1**	43,994	3.9	59.0
11 to 20s	108,304	**5.3**	**1,238**	18.8	1.1	34,782	3.7	**32.1**	72,284	6.5	66.7
21 to 60s	206,798	**10.0**	**2,944**	44.8	1.4	65,012	6.9	**31.4**	138,842	12.4	67.1

Table 24

Total markup values for all potential RPT pairs with time between trades of one minute or less and with markups of greater than 10 bp in absolute value among all filtered bond trades in the TRACE Full Year sample, by elapsed time between trades in the RPT pair. The RPT markup is the difference between the two trade prices in the pair. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, the markup is the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving dealer purchase from a customer. The total markup value is the summed product over all RPT pairs (counting one side only) of the RPT markup times the trade size. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

Elapsed time between trades in the RPT pair	**N**	**Mean RPT markup (bp)**	**Total markup value ($M)**	**Total dollar trade volume ($B)**
≤1 minute (potential RPT)	767,722	**76.6**	**602**	**185**
≤ 1 second (potential electronic RPT)	474,403	**70.6**	137	26
0s	405,271	**70.6**	113	20
1s	69,132	**70.1**	24	6
2s	43,001	**86.2**	16	3
3s	21,451	86.8	11	2
4s	11,224	87.0	8	2
5s	9,097	82.3	8	2
6 to 10s	33,997	84.3	47	16
11 to 20s	59,366	81.5	130	48
21 to 60s	115,183	90.2	243	85

Table 25

Total markup values for all potential RPT pairs with time between trades of one minute or less and with markups of greater than 10 bp in absolute value among all filtered bond trades in the TRACE Full Year sample, by trade size. The RPT markup is the difference between the two trade prices in the pair. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, the markup is the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving dealer purchase from a customer. The total markup value is the summed product over all RPT pairs (counting one side only) of the RPT markup times the trade size. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

Trade size in par value	**N**	**Percent**	**Mean RPT markup (bp)**	**Total markup value ($M)**	**Total dollar trade volume ($B)**
All trade sizes	767,722	100.0	76.6	**602**	185
$100K (Retail-size)	692,940	**90.3**	**79.0**	**138**	16
>$100K (Institutional-size)	74,782	9.7	**54.7**	**464**	169
$100K< - $1M	53,352	6.9	**65.5**	93	17
Trades marked 1MM+	18,232	2.4	**28.1**	293	118
$1M< - $5M	2,356	0.3	**26.5**	17	7
Trades marked 5MM+	842	0.1	**22.7**	61	27

Table 26

Total markup values for all potential RPT pairs with time between trades of one minute or less and with markups of greater than 10 bp in absolute value among all filtered bond trades in the TRACE Full Year sample, by RPT pair type. A normal RPT involves a dealer trade with a customer and an interdealer trade. A dealer-intermediated crossing RPT involves two offsetting dealer trades with customers. The total markup value is the summed product over all RPT pairs (counting one side only) of the RPT markup times the trade size. The RPT markup is the difference between the two trade prices in the pair. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, the markup is the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving a dealer purchase from a customer. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

	Riskless principal trade pair type														
	Dealer bought from customer seller					**Dealer sold to customer buyer**					**Dealer-intermediated crossing RPT**				
Trade size in par value	**N**	**% of row**	**Mean RPT markup (bp)**	**Total markup value ($M)**	**Total dollar trade volume ($B)**	**N**	**% of row**	**Mean RPT markup (bp)**	**Total markup value ($M)**	**Total dollar trade volume ($B)**	**N**	**% of row**	**Mean RPT markup (bp)**	**Total markup value ($M)**	**Total dollar trade volume ($B)**
All trade sizes	277,537	**36.2**	**61.8**	**115**	29	446,225	**58.1**	88.6	**176**	28	43,960	**5.7**	**49.7**	**312**	129
$100K (Retail-size)	256,217	37.0	62.5	36	6	419,610	60.6	89.3	98	10	17,113	**2.5**	74.6	4	1
>$100K (Institutional)	21,320	28.5	53.7	79	23	26,615	35.6	76.6	78	18	26,847	35.9	33.8	307	128
$100K< - $1M	18,596	34.9	56.6	29	6	24,825	46.5	79.9	49	7	9,931	18.6	45.9	16	5
Marked 1MM+	2,122	11.6	34.4	40	13	1,118	6.1	31.3	21	7	14,992	**82.2**	27.0	233	98
$1M< - $5M	509	21.6	31.1	4	1	591	25.1	27.6	4	2	1,256	53.3	24.2	9	4
Marked 5MM+	93	11.0	22.7	7	3	81	9.6	18.9	5	3	668	79.3	23.2	50	21

Table 27

Total markup values for all potential RPT pairs with time between trades of one minute or less and with markups of greater than 10 bp in absolute value among all filtered bond trades in the TRACE Full Year sample, by whether the customer paid a commission. The total markup value is the summed product over all RPT pairs (counting one side only) of the RPT markup times the trade size. The RPT markup is the difference between the two trade prices in the pair. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, the markup is the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving a dealer purchase from a customer. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

	Commission paid in RPT									
	None					**Yes**				
Trade size in par value	**N**	**Percent of row**	**Mean RPT markup (bp)**	**Total markup value ($M)**	**Total dollar trade volume ($B)**	**N**	**Percent of row**	**Mean RPT markup (bp)**	**Total markup value ($M)**	**Total dollar trade volume ($B)**
All trade sizes	696,190	90.7	**81.3**	598	184	71,532	**9.3**	**31.5**	4	2
$100K (Retail-size)	622,943	89.9	**84.3**	136	15	69,997	10.1	**31.7**	2	1
>$100K (Institutional-size)	73,247	97.9	55.3	463	169	1,535	2.1	**22.8**	2	1
$100K< - $1M	51,881	97.2	66.7	92	17	1,471	2.8	22.7	1	0
Trades marked 1MM+	18,190	99.8	28.1	292	118	42	0.2	35.2	1	0
$1M< - $5M	2,335	99.1	26.7	17	7	21	0.9	3.4	0	0
Trades marked 5MM+	841	99.9	22.7	61	27	1	0.1	18.0	0	0

Table 28

Frequencies of the order in which dealers report the two trades in an RPT pair, classified by the type of RPT pair. The rows of this table present results for each type of RPT. The columns indicate which trades the dealer reports. Each trade in the RPT appears in in two columns and two rows of the table. The first trade reported appears in the column corresponding to the trade side that the dealer first reported. The second trade report will appear in another column. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bonds trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The Full Year data include all 9,883,107 such trades on 252 trading days spanning April 1, 2014 to March 31, 2015. Numbers in bold are those referred to in the text.

		Reported dealer side of trade							
		Dealer trades with all customers		Dealer bought from customer		Dealer sold to customer		Interdealer trades	
Dealer role in RPT pair	**Trade sequence in RPT pair**	**N**	**% of row**	**N**	**% of row**	**N**	**% of row**	**N**	**% of row**
All normal RPTs	**1st trade**	328,298	45.4	130,646	18.1	197,652	27.3	395,464	**54.6**
	2nd trade	395,464	54.6	146,891	20.3	248,573	34.3	328,298	45.4
Dealer bought from customer seller	**1st trade**	130,646	47.1	130,646	47.1	n/a	n/a	146,891	**52.9**
	2nd trade	146,891	52.9	146,891	52.9	n/a	n/a	130,646	47.1
Dealer sold to customer buyer	**1st trade**	197,652	44.3	n/a	n/a	197,652	44.3	248,573	**55.7**
	2nd trade	248,573	55.7	n/a	n/a	248,573	55.7	197,652	44.3
All crossing RPTs (Dealer intermediated between two customers)	**1st trade**	43,960	100.0	30,252	**68.8**	13,708	31.2	n/a	n/a
	2nd trade	43,960	100.0	13,708	31.2	30,252	68.8	n/a	n/a

Table 29

Trade throughs with price improvements of less than -10 bp in all filtered TRACE trades in the Primary Period sample, by whether the trade through is a member of a potential RPT pair for which the elapsed time between the two trades in the pair is one minute or less. A trade through occurs when the trade price is above the ask or below the bid. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The RPT markup is the difference between the two trade prices in the pair. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, the markup is the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving dealer purchase from a customer. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

				RPT markup								
	All trade throughs			**Zero markup**			**Non-zero markup**			**Not a RPT**		
Type of RPT	**N**	**% of all trade throughs**	**% of row**	**N**	**% of all trade throughs**	**% of row**	**N**	**% of all trade throughs**	**% of row**	**N**	**% of all trade throughs**	**% of row**
All trade throughs	461,575	100.0	100.0	39,549	100.0	8.6	148,936	100.0	32.3	273,090	100.0	59.2
All RPTs	**188,485**	**40.8**	100.0	39,549	100.0	21.0	148,936	100.0	**79.0**	n/a	n/a	n/a
Normal RPT	171,903	37.2	100.0	29,949	75.7	17.4	141,954	95.3	82.6	n/a	n/a	n/a
Crossing RPT	**16,582**	3.6	100.0	9,600	24.3	57.9	6,982	4.7	42.1	n/a	n/a	n/a
Not a RPT	273,090	59.2	100.0	n/a	n/a	n/a	n/a	n/a	n/a	273,090	100.0	100.0

Table 30

The distribution of the sum of the customer price improvement plus dealer markup for all trade throughs that are also potential RPTs in the Primary Period sample. The sample includes only trade throughs for which price improvement is less than -10 bp and RPTs for which the elapsed time between the two trades in the pair is one minute or less. A trade through occurs when the trade price is above the ask or below the bid. A potential RPT (riskless principal trade) pair is a pair of adjacent trades in a size run for which one of the two trades is a dealer trade with a customer and the other trade is an interdealer trade (a normal RPT pair), or for which both trades are with customers and the dealer is on opposite sides (a crossing RPT pair), and which does not overlap an earlier RPT pair. A size run is a sequence of two or more trades adjacent in time with the same trade sizes. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The RPT markup is the difference between the two trade prices in the pair. For crossing RPT trade pairs involving dealer trades with a customer buyer and with a customer seller, the markup is the difference between the dealer's sales price to the buyer and the purchase price from the seller. For normal RPT trade pairs involving an interdealer trade and a sale to a customer, the markup is the customer's purchase price minus the interdealer trade price, and vice versa for normal pairs involving a dealer purchase from a customer. The filtered bond trades include only bond trades during normal trading hours that were not subsequently cancelled, on all CUSIP-days for which the average trade price was 10 or more, with no irregular pricing or settlement condition codes. The subset data include only those trades for which at least one quote appears in the IB quote data on the trade date. The Primary Period spans December 15, 2015 to March 31, 2015 and includes 77 trading days. Numbers in bold are those referred to in the text.

					RPT markup inbp plus price Improvement inbp						
Type of RPT	**N**	**% of all trades**	**RPT markup (bp)**	**Mean price improvement (bp of price)**	**Mean**	**Std**	**P10**	**Q1**	**Median**	**Q3**	**P90**
All RPTs that	148,936	100.0	78	-85	-6	40	-35	-10	-0	3	18
Normal RPT	141,954	95.3	**80**	**-86**	**-6**	**37**	-32	-9	**0**	3	17
Crossing RPT	6,982	4.7	**41**	**-56**	-16	**74**	-81	-31	-12	6	41

Table 31

Estimated OLS regressions for relative transaction costs measured in basis points. The sample includes all filtered TRACE customer trades in the Primary Period subset sample for which the time since quote is 2 seconds or more, except trades with suspected bad data. *InvDollarSize* is the inverse of the par value size of the trade. *InvPrice* is the inverse of the trade price. *TradeSize* is the size of the trade in number of bonds (par value size ÷ 1000) with size set to 6,680 and 29,353 bonds (the 2012 mean sizes) for trades reported to be above $1M and $5M in par value. *InvtGradeTradeSize* is the size of the trade in number of bonds for bonds (all investment grade) with reported par value size of $1M<-$5M or with size reported to be over $5M, and zero otherwise. *LargeInvtGrade* indicates bond trades with reported par value size of $1M<-$5M or with size reported to be over $5M. *LargeSpecGrade* and *LargeInvtGrade* indicate whether the bond trade is marked as over $1M or $5M in par value. *DealerSide* indicates whether the dealer sold to the customer. *CommissionTrade* indicates whether the dealer collected a commission on the trade. *NormalMarkupBP* is the RPT markup in basis points, if the trade was part of a normal RPT (those involving an interdealer trade) and zero otherwise. *CrossingMarkupBP* is the RPT markup for crossing RPTs (dealer-intermediated customer-to-customer RPTs) and zero otherwise. *ZeroMarkup* indicates whether the markup is zero for RPTs, which are likely agency trades. *Electronic* indicates whether the time between the trades in a RPT is 2 seconds or less and zero otherwise. *AbsTransRet* is the absolute price return in basis points from the previous trade (0 if the previous trade was on a different day). *LogTotalDaysTraded* is the total number of days the bond traded during the year. *LogTotalTrades* is the total number of TRACE trades during the year. *LogTotalTradesOnDay* is the total number of trades in the bond on the day of the trade. *LogPrice* is the log bond price. *AverageTradeSize* is the average trade size in bonds (par value size ÷ 1,000) during the year. *Retail* indicates a trade with par value size of less than $100,000. *TradeClassification* classifies the trades by one of 5 types: 1) a normal RPT trade, 2) a crossing RPT trade, 3) not an RPT trade in a size-run episode with a RPT trade, 4) trade in a size-run that does not have an RPT trade, and 5) trade not in a size-run. The regression sample includes 1,177,773 trades arranged during the 77-day long trading period between December 15, 2015 to March 31, 2015.

(Continued)

Table 31, Continued

	Simple OLS regression			OLS regression with each regressor interacted with *Retail* × *DealerSide* × *TradeClassification*	
Regressor	**Estimate**	**Standard error**	***t*-value**	**Degrees of freedom**	**Type III F-value**
Intercept	1122	7.4	151	7	34
InvDollarSize	-0.89	0.040	-22	20	775
InvPrice	-5.6	0.095	-59	20	352
TradeSize	-0.069	0.00064	-107	20	373
InvtGradeTradeSize	0.063	0.00064	98	20	23
LargeSpecGrade	27	0.57	47	10	1.83
LargeInvtGrade	159	2.4	66	10	2.87
DealerSide	18	0.11	162		
CommissionTrade	-5.0	0.34	-15	20	33
NormalMarkupBP	0.90	0.0017	525	4	77033
CrossingMarkupBP	0.31	0.0035	87	4	1611
ZeroMarkup	20	0.16	122	8	37
Electronic	8.4	0.18	47	8	61
AbsTransRet	5.7	0.35	16	20	137
LogTotalDaysTraded	-3.2	0.15	-21	20	324
LogTotalTrades	-4.3	0.094	-46	20	484
LogTotalTradesOnDay	-1.8	0.070	-27	20	624
InvtGrade	-19	0.16	-120	20	265
LongTerm	37	0.16	224	20	2876
ShortTerm	-18	0.18	-99	20	668
Floating	0.21	0.25	0.84	20	129
HighRate	19	0.13	140	20	1118
LowRate	-17	0.22	-78	20	394
LogPrice	-211	1.4	-150	20	1583
AverageTradeSize	-0.0080	0.000065	-122	20	1047
Total degrees of freedom		25		391	
R^2 =40.4%				R^2 = 50.3%	

Note that degrees of freedom in the interaction regression vary by the various regressors because many regressors have zero values for all trade classifications. For example, *NormalMarkupBP* only adds 4 degrees of freedom because it only has non-zero values for one level of *TradeClassification* (normal RPT trade). The four levels correspond to two *Retail* levels (retail-size or institutional-size) times two *DealerSide* levels (dealer sold to customer or dealer bought from customer). *DealerSide* does not appear on a line in the interaction model results because it is crossed with all the other variables.