JOURNAL OF FINANCIAL AND QUANTITATIVE ANALYSIS Vol. 55, No. 1, Feb. 2020, pp. 1–45

doi:10.1017/S0022109019000231

A Survey of the Microstructure of Fixed-Income Markets

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Abstract

In this article, we survey the literature that studies fixed-income trading rules and outcomes, including Treasury securities, corporate and municipal bonds, and structured credit products. We compare and contrast the microstructure and regulation of fixed-income markets with equity markets. We highlight the nature of over-the-counter trading in the face of search costs and the associated slow evolution of electronically facilitated intermediation. We discuss the databases available to study fixed-income microstructure, as well as measures and determinants of trading costs, and the important roles dealer networks and limited transparency play. We also highlight unresolved issues.

I. Introduction

Financial markets create and transact a broad set of fixed-income instruments, characterized by contracts that specify the amount and timing of promised payments. With a few exceptions to be noted, fixed-income instruments trade in dealer-oriented over-the-counter (OTC) search markets that differ significantly from the more widely-studied markets for equity instruments.

Treasury securities issued by central governments are in many ways the simplest fixed-income instruments, characterized by low default risk, high trading volumes, standardized contracts, and generally liquid markets. Bonds issued by corporations as well as municipalities constitute one of the largest segments of the fixed-income markets. In addition, fixed-income markets trade structured products, which are created by repackaging existing loans. Examples include mortgage-backed securities (MBS), either with (agency MBS) or without (private-label MBS) the implicit backing of semi-government agencies; asset-backed securities (ABS), which are secured by assets such as auto loans or credit card debt;

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and packages of bank loans. Fixed-income markets also include collateralized debt obligations (CDOs), which are created from structured products by dividing cash-flow promises into various "tranches."[1]

In general, fixed-income trading has been the focus of less research attention as compared to equity market trading, despite the fact that fixed-income markets are substantially larger and account for more capital raising as compared to equity markets (discussed further in Section III.A). Recent years have seen an increase in research, both theoretical and empirical, focused on fixed-income trading. This article reviews and summarizes the key issues and many of the important studies, while laying out directions for potential future research.

II. Fixed-Income versus Equity Markets

Fixed-income and equity markets share important common features. Each facilitates price discovery and the completion of transactions in financial assets. Investors seeking to buy and to sell do not necessarily arrive simultaneously in these markets, so intermediaries emerge to supply liquidity. When these intermediaries trade on a principal basis, they absorb order imbalances into inventory and therefore are subject to price risk on the positions entered to facilitate transactions. Because the value of both fixed-income and equity instruments depends on marketwide variables, such as central bank policy and macroeconomic growth, as well as issuer-specific outcomes, and because some participants may have better access to such information than others, risks attributable to asymmetric information arise in both markets. Microstructure theory broadly applied therefore implies that the costs of demanding immediate trade execution in both equity and fixed-income markets should depend on return volatility, customer arrival rates, and the likelihood of information asymmetries adverse to the intermediaries who effectively supply liquidity.

A. Contrasts between Fixed-Income and Equity Microstructures

Despite these similarities in the underlying economic issues, fixed-income microstructure differs significantly from that of the equity markets. Although most equity trading has migrated in recent years to electronic limit order markets, with the exception of U.S. Treasury instruments and to-be-announced MBS (TBA MBS, discussed further later), relatively little fixed-income trading occurs on electronic platforms.[2] For example, a recent industry report estimated that just 19% of U.S. investment-grade corporate bond trading was electronically facilitated, mostly through requests for quotations (RFQs) transmitted to established dealers https://www.greenwich.com/fixed-income-fx-cmds/corporate-bond-electronic-trading-continues-growth-trend (July 28, 2016). Hendershott and Madhavan (2015) describe trading on the basis of indicative RFQs on MarketAxess. Clients select the number of dealers to be queried for

[1] See the Financial Industry Regulatory Authority's (FINRA) 2017 TRACE Fact Book for detailed definitions of debt instruments (http://www.finra.org/sites/default/files/2017-trace-fact-book.pdf).

[2] Abudy and Wohl (2018) examine Tel Aviv Stock Exchange data in 2014, where corporate bonds trade in a consolidated limit order book market structure, reporting that the market is liquid with narrow spreads and smaller price dispersion.

a quote of a specified size in a given bond and specify the time by which quotes should be submitted. At that time, all quotes are revealed to the client. If satisfied, the client can contact the dealer submitting the best quote for execution. Hendershott and Madhavan report that RFQ usage is greatest for recently issued, investment-grade, large-issue-size bonds.[3]

Quotations in equity markets are firm, in that the submission by another market participant of an opposite-direction order with a sufficiently aggressive limit price generates an immediate trade execution. In contrast, fixed-income quotes are typically indicative rather than firm commitments. Fixed-income trading is often facilitated by the electronic dissemination of quotations to at least some participants, even though trades cannot be automatically completed on the same platforms. The lack of electronically executable quotations has largely kept high-frequency trading (HFT) firms from establishing themselves as major players in the fixed-income markets. As a consequence, most liquidity provision in fixed-income markets continues to rely on dealer firms, with little direct access by public orders.[4] The situation is analogous to the design of the National Association of Securities Dealers Automated Quotations (NASDAQ) equity markets, before the establishment of order-handling rules 2 decades ago.

Nevertheless, the electronic facilitation of bond trading is increasing. In Treasury markets, most interdealer trading is now electronic and automated, and a large share of customer-to-dealer trading relies on electronic communication. Platforms that allow for direct customer-to-customer (or “all-to-all”) trading have been introduced to corporate bond markets, though their share of trading remains low. Furthermore, some liquidity providers now respond to corporate bond RFQs for trades below certain size thresholds using algorithms rather than human traders (https://www.greenwich.com/press-release/robots-have-entered-corporate-bond-market).

The equity markets are highly transparent, as prices and quantities for completed trades (“post-trade transparency”) as well as the best available bid and ask quotes (“pre-trade transparency”) are widely disseminated in real time or with very short delays.[5] In contrast, as discussed further in Section VI, fixed-income markets are relatively opaque, as quotations are distributed to only some market participants. The various market venues that trade equities are integrated by both regulation and competition. Regulation NMS (National Market System) in particular requires that no equity trade of limited size be executed at a price worse than the best electronically accessible quotation on any exchange. Fixed-income markets are not subject to a similar regulation. Although, as discussed further in Section VI, brokerage firms are subject to a duty of best execution,

[3]MarketAxess reportedly holds an 85% market share in electronically facilitated corporate bond trading (see Leising, M., and M. Smith. “Electronic Bond Trading Gains Ground.” Bloomberg. Available at https://www.bloomberg.com/news/articles/2018-02-15/electronic-bond-trading-gains-ground-as-market-finally-matures (Feb. 15, 2018)).

[4]Biais and Green (2019) show that municipal and corporate bonds traded actively on the New York Stock Exchange (NYSE) before World War II (WWII). The study estimates that average trading costs for retail bond investors on the NYSE before WWII were lower than they are over-the-counter in recent years.

[5]“Dark pools,” which do not generally disseminate quotations, are an exception.

the enforcement of such a duty is potentially hindered by the lack of pre-trade transparency in fixed-income markets. In addition, each equity exchange disseminates electronic quotations that facilitate competition, resulting in what O'Hara and Ye (2011) refer to (page 459) as "a single virtual market with multiple points of entry." In contrast, competition across fixed-income dealers may be mitigated by limited pre-trade transparency and high search costs.

Bonds, like common stocks, can be sold short by borrowing the security. Short selling facilitates market making by allowing dealers to accommodate customer buy orders, even if the bond is not already held in inventory. Short selling also facilitates speculative trading motivated by the possibility of a price decline. A large literature studies short selling in the stock markets, generally concluding that short selling enhances liquidity (Beber and Pagano (2013)) and, because short sellers are relatively well informed (Diamond and Verrecchia (1987)), they improve price discovery. In contrast, the literature on short selling in bond markets is sparse.

B. Dealer Capital Commitment

With the exception of Treasury securities and TBA MBS, trading in fixed-income instruments is dominated by OTC trading between customers and dealer firms. Traditionally, dealers committed their own capital, completing most trades on a principal basis by absorbing customer orders into inventory. In recent years, however, dealers have reduced their degree of capital commitment in corporate bond markets, as documented by Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018) and Bao, O'Hara, and Zhou (2018). This reduction reflects in part an increased reliance on "prearranged" pairs of trades, where the dealer quickly resells the bond to a counterparty, who was in fact located before the completion of the initial trade (Schultz (2017), Goldstein and Hotchkiss (2020), and Choi and Huh (2017)). Furthermore, Hollifield, Neklyudov, and Spatt (2017) document shorter "intermediation chains," that is, that fewer dealers are involved before a bond is transferred to another customer.

Most major bond dealers are affiliated with banks, though nonbank dealers have increased their participation in recent years. For example, Bessembinder et al. (2018) report that nonbank dealers accounted for 12.5% of customer–dealer trading volume in corporate bonds during 2014–2016, as compared to just 2.4% before the 2007–2009 financial crisis. Decreased capital commitment by corporate bond dealers in recent years has been linked to post-financial crisis regulations, including higher capital requirements and the Volcker Rule limitations on trading by banks, as discussed further in Section VI.

C. Trading Outcomes

Several empirical patterns differ notably across equity and fixed-income markets. Customer trade execution costs tend to be substantially larger in fixed-income markets as compared to equities.[6] For example, Harris and Piwowar (2006) document that effective bid–ask spreads in municipal bonds averaged approximately 2% for trades of $20,000. For the cost of a similar-sized trade in a

[6]Treasuries, where interdealer trades occur at very narrow spreads, and TBA MBS comprise potential exceptions. Data on customer trades in Treasury securities are not publicly disseminated.

$40 stock to be as large, the effective bid–ask spread would be 80 cents, whereas by comparison, Chordia, Roll, and Subrahmanyam (2008) report that the actual median effective bid–ask spread in U.S. equity markets at a similar point in time is just 3.3 cents. This outcome is surprising, as fixed-income markets tend to be less volatile than equities and fixed-income securities are likely to be less sensitive to new information regarding issuer fundamentals. That is, standard microstructure arguments imply a lower cost of immediacy in fixed-income markets, because the intermediaries who supply liquidity are likely subject to both less inventory risk and asymmetric information costs.

It is also noteworthy that although trade execution costs in equity markets tend to be greater for large trades than for small ones, presumably because of adverse selection and inventory costs, the opposite pattern is observed in fixed-income markets. For example, Edwards, Harris, and Piwowar (2007) report estimated trading costs for corporate bonds that decrease monotonically from 75 basis points (bps) for trades of $5,000 to less than 10 bps for trades of $1 million or larger. Similarly, Bessembinder, Maxwell, and Venkataraman (2013) report estimates of trading costs for structured credit products (ABS, MBS, etc.) that range from 83 bps for trades less than $100,000 to just 5 bps for trades larger than $1 million.

Trade sizes and frequencies also differ dramatically across equity and bond markets. In recent years, the median trade size in equity markets is 100 shares (O'Hara and Ye (2014)), or approximately $3,000 to $5,000 for typically priced stocks. By comparison, a "round-lot" trade in corporate bond markets involves $1 million. Bessembinder et al. (2018) report an average trade size of $1.2 million for their sample of corporate bond trades during 2014–2016, and Bessembinder, Kahle, Maxwell, and Xu (2009) report that round-lot transactions accounted for nearly 90% of corporate bond dollar trading volume.

Most fixed-income products trade infrequently. For example, Bessembinder et al. (2013) report that the majority of MBS and ABS (e.g., credit cards and auto loans) in their 21-month sample never traded at all. Edwards et al. (2007) report that individual corporate bond issues did not trade on 52% of the days in their sample and that the average number of daily trades in an issue, conditional on trading, is just 2.4. One reason that individual corporate bonds trade less frequently than equities is that an issuer often has multiple bond issues outstanding. Although equity shares issued at different points in time by a given firm are fully substitutable, each bond issue is a distinct contract with differing promised payments, maturity dates, and priority in case of default, and is therefore traded separately.

III. Descriptive Overview of Fixed-Income Markets

A. Bond Market Size and Ownership

According to Securities Industry and Financial Markets Association (SIFMA) statistics summarized on Table 1, as of 2017 the largest capital markets relative to the gross domestic product (GDP) are those of the United States (360%) and Japan (388%), followed by the European Union (245%) and China (167%) (https://www.sifma.org/resources/research/us-capital-markets-deck-2018/). Fixed-income markets account for 56% of U.S. capital markets,

TABLE 1
Size, Issuance, and Ownership in Bond Markets

Table 1 reports the size of the Treasury, money market, agency debt, mortgage-backed securities, corporate bonds, municipal bonds, and U.S. equity markets as of the end of 2017. Issuance refers to the extent of capital raising in each market segment in 2017. Ownership refers to the percentage of outstanding securities held by each category of investors. FHLB stands for Federal Home Loan Bank. Data sources are reported in the table footnotes.

Type of Bond	Issuer	Outstanding ($B, 2017)[a]	Issuance ($B, 2017)[a]	Ownership (as of 2016)
Treasury	U.S. Treasury	14,450	2,200	Foreign (42%), Federal Reserve (17%), mutual funds (12%), pension funds (10%), banks (5%), insurance (2%)[b]
Money market	U.S. Treasury, financial institutions, corporations	950	—	
Agency debt	Freddie Mac, Fannie Mae, FHLBs	1,950	750	
Mortgage-backed securities	Financial institutions	9,300	2,000	Foreign (14%), Federal Reserve (20%), mutual funds (11%), insurance/pension (9%), banks (25%)[c]
Asset-backed securities	Financial institutions	1,450	600	
Corporate	Corporations	9,000	1,650	Foreign (29%), insurance companies (27%), mutual funds (16%), pension funds (10%), households (6%), banks (7%)[d]
Municipal	State and local governments and agencies	3,850	450	Households (51%), banks (30%), mutual funds (17%)[e]
U.S. fixed income		40,950	7,650	
U.S. stock market	Corporations	32,100	224	
U.S. capital markets		73,050	7,874	
U.S. GDP		19,400		

[a] Securities Industry and Financial Markets Association (SIFMA) 2018.
[b] Board of Governors of the Federal Reserve System, Financial Accounts of the United States.
[c] Gao, Schultz, and Song (2017).
[d] Federal Reserve Flow of Funds.
[e] Municipal Securities Rulemaking Board (MSRB), Trends in Municipal Bond Ownership, 2017.

based on market capitalization. Figure 1 displays the relative size of various U.S. fixed-income markets from 2003 to 2017, and for comparison the size of U.S. public equity markets, demonstrating that the fixed-income market in aggregate is substantially larger than the equity market. Fixed-income markets accounted for 97% of all U.S. security issuance during 2017. The volume of new issuance reflects in part that many fixed-income securities have short terms and are reissued (i.e., refunded) at maturity. Treasury bonds accounted for 29% of all issuance, whereas mortgage-related and corporate issuances accounted for 26% and 22%, respectively.

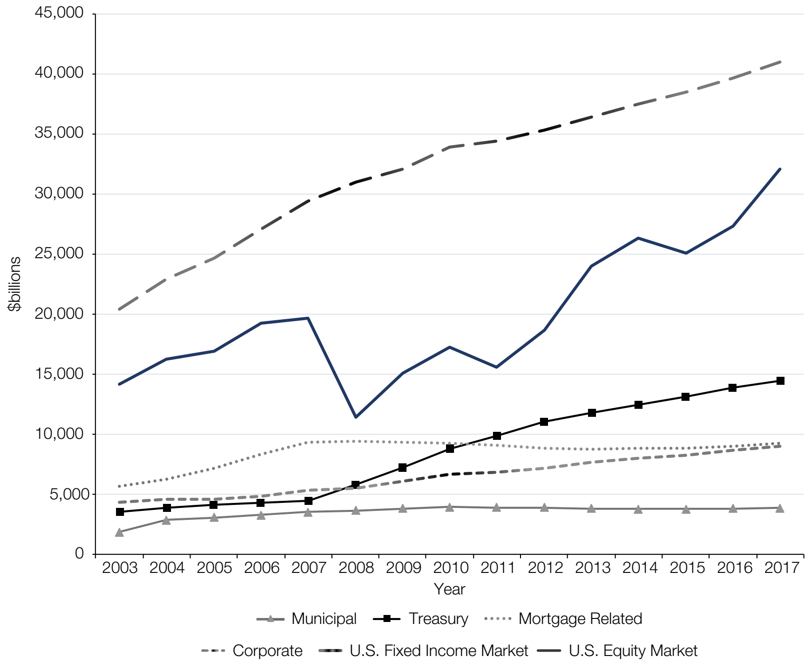
Foreign investors held 42% of outstanding U.S. Treasury bonds as of 2016 and were also significant holders of corporate bonds (29% of total) and agency MBS (14% of total).[7] The U.S. Federal Reserve (Fed) has been a large owner of

[7]Foreign ownership includes the holdings of foreign subsidiaries of U.S. corporations.

FIGURE 1

Size of Equity and Fixed-Income Markets (2003–2017)

Figure 1 reports the size of the Treasury, mortgage-related, corporate bond, municipal bonds, U.S. equity, and U.S. fixed-income markets as of year-end between 2003 and 2017. *Source:* Author calculations based on data provided by Securities Industry and Financial Markets Association (SIFMA).



Treasury bonds and agency MBS. The Fed held significant quantities of bonds even before the 2007–2009 financial crisis, but its holdings of Treasury and MBS securities spiked as a result of asset purchase programs during the crisis. Direct holdings by households account for less than 10% of all Treasury and corporate bond holdings. In contrast, households account for more than 50% of municipal bond holdings, reflecting their federal tax-exempt status. Mutual funds account for 12%, 17%, and 16%, respectively, of holdings of Treasury, municipal, and corporate bonds (each as of 2016).

B. Bond Trading Participation and Logistics

The trading activity in the secondary market for fixed-income securities is dominated by institutions, such as pension funds, mutual funds, hedge funds, insurance companies, and sovereign wealth funds. Quotation data are available to such institutions. Investment-grade bonds are quoted in terms of spread over a Treasury security of similar maturity. Lower rated bonds, the value of which depends more on firm-specific information (Schultz (2001)), are quoted in dollars. Dealers broadcast indicative bids and offers on lists of actively traded bonds (called “runs”) to potential institutional clients. In the past, dealers broadcast runs once a day, but in recent years, runs are updated many times daily using automated pricing models. Data aggregators (e.g., Bloomberg or Algomi ALFA) provide buy-side institutions with information from multiple sources, including recent transactions, proprietary dealer runs, quotations from electronic bond platforms, and electronic RFQ platforms (e.g., MarketAxess). Institutions can contact dealers, via instant messaging or phone, to obtain information on a bond that is not quoted, to obtain "color" on market conditions, or to negotiate the terms of a transaction. In some cases, institutional customers submit bid or offer wanted in competition (BWIC or OWIC, respectively) lists to dealers, requesting quotations on a specified set of bonds. Newer all-to-all trading venues (e.g., Trumid or MarketAxess's Open Trading) offer institutions the ability to trade directly with each other, use hidden order types, and allow for midpoint pricing. Retail investors purchase and sell bonds through retail brokers, and generally do not have direct access to dealer quotations.

Dealer firms trade with one another in the interdealer market, either directly or on interdealer broker (IDB) platforms, some of which offer fully electronic trading as well as over-the-phone trading via voice-assisted brokers. For corporate and structured bonds, transactions among dealers are most often completed on a bilateral basis using traditional (voice) methods. For U.S. Treasuries, about 70% of interdealer trading occurs on electronic IDB platforms (e.g., BrokerTec), where nondealer participants, such as hedge funds and principal trading firms (HFTs), also participate. Wu (2018) reports that 60% of the interdealer trades in municipal bonds occur on electronic alternative trading systems.[8]

U.S. Securities and Exchange Commission (SEC)-registered broker-dealers and trading platforms are required to report their transactions in Treasury, corporate, and structured bonds to FINRA, and in municipal bonds to the Municipal Securities Rulemaking Board (MSRB). With the exception of Treasury bonds and some categories of structured bonds, data on completed transactions are made available to the public. Mandatory reporting of trade prices for most credit instruments was phased in, beginning in 2002, according to the timeline summarized on Table 2. Before 2002, there was no comprehensive reporting of bond transaction data to regulators or the public.[9]

C. Data Sources for Fixed-Income Microstructure Studies

Table 3 summarizes sources of historical fixed-income data. Secondary market transaction data, including both dealer-to-customer trades and interdealer trades, are publicly available from MSRB through the Electronic Municipal Market Access (EMMA) platform for municipal bonds and from FINRA through the Trade Reporting and Compliance Engine (TRACE) platform for corporate bonds and structured products. For each trade, the data include the bond CUSIP (Committee on Uniform Securities Identification Procedures) number, trade time, price, transacted quantity (to a specified maximum reportable size), indication of whether the trade was interdealer or dealer-customer, as well as a buy–sell

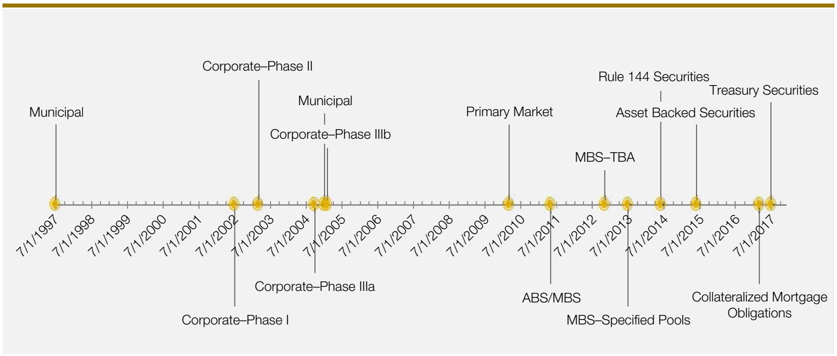
[8]For Treasury statistics, see http://libertystreeteconomics.newyorkfed.org/2018/09/unlocking-the-treasury-market-through-trace.html. For municipal bond statistics, see Wu (2018).

[9]A partial exception is the U.S. Treasury markets. In June 1991, GovPX was launched under SEC guidance to provide institutional market participants with real-time interdealer book and transactions data in Treasury securities. Because reporting was voluntary, GovPX's coverage of the interdealer Treasury market varied between 66% in the early 1990s to less than 42% in 2001.

TABLE 2

Regulatory Data Collection and Post-Trade Reporting in U.S. Fixed-Income Markets (1997–2017)

Table 2 describes the timeline for regulatory data collection and post-trade reporting between 1997 and 2017 for U.S. municipal bonds, corporate bonds, agency debentures, asset-backed securities, mortgage-backed securities, and Treasury security markets. Data sources are the Municipal Securities Rulemaking Board (MSRB) 2017 Fact Book for the municipal market and the Financial Industry Regulatory Authority (FINRA) TRACE 2017 Fact Book for other fixed-income markets. Transactions that exceed a size threshold are reported with quantity field = Threshold+. For example, the threshold for Investment Grade corporates (i.e., rated Baa (by Moody's) or BBB (by S&P and Fitch) or above) is $5 million and for High Yield corporates (i.e., those with lower credit ratings than investment grade) is $1 million. Transactions that exceed the thresholds are reported as $5 million+ and $1 million+, respectively. *Source:* 2017 FINRA Fact Book; FINRA Rulings.



Transparency Timeline

Date	Milestone	Notes
July 1997	Municipal	Dealers report all municipal bond transactions to MSRB after close of business each day. Publicly disseminated after 2 weeks.
July 2002	Corporate–Phase I	Dealers report all corporate bond transactions to FINRA within 75 minutes. Public dissemination is immediate for large 500 IG and 50 HY bonds. Transactions in other bonds are not disseminated.
Mar. 2003	Corporate–Phase II	Public dissemination is expanded to smaller IG bonds in Mar. 2003 and further expansion to approximately 4,650 corporate bonds in Apr. 2003. Reporting lag is reduced to 45 minutes in Oct. 2003.
Oct. 2004	Corporate–Phase IIIa	Additional corporate bonds are included for public dissemination. Reporting lag is reduced to 30 minutes.
Jan. 2005	Municipal	Dealers report all municipal bond transactions to MSRB within 15 minutes. Public dissemination is immediate.
Feb. 2005	Corporate–Phase IIIb	Additional corporate bonds are included for public dissemination. Approximately 99% of transactions in registered corporate are covered. Reporting lag is reduced to 15 minutes in July 2005. All registered corporate bonds are disseminated by Jan. 2006.
Mar. 2010	Primary market	Dealers report all U.S. agency debenture transactions, as well as primary market transactions in TRACE-eligible securities.
May 2011	ABS/MBS	Dealers report all transactions in asset-backed securities (ABS) and mortgage-backed securities (MBS) to FINRA. These trades are not publicly disseminated.
Nov. 2012	MBS–TBA	To-be-announced (TBA) transactions are included for public dissemination.
July 2013	MBS–Specified pools	MBS transactions are included for public dissemination.
June 2014	Rule 144 securities	Transactions in U.S. Securities and Exchange (SEC) Rule 144A Corporate securities are included for public dissemination.
June 2015	Asset-backed securities	Transactions in ABS are included for public dissemination.
Mar. 2017	Collateralized mortgage obligations	Transactions in collateralized mortgage obligations are included for public dissemination.
July 2017	Treasury securities	Dealers report all Treasury security transactions to TRACE. Transactions are not reported to the public.

TABLE 3
Data Sources, Trading Platforms, and Trading Activity

Table 3 reports transaction data sources, data coverage period, daily trading volume (in $ billion), average transaction size (in $ million), percentage of trading volume that is dealer to customer, trade execution costs based on dealer-to-customer trades (in basis points), and the dominant trading platforms for Treasury securities, agency mortgage-backed securities that specify pools (MBS) and to-be-announced (TBA), commercial mortgage-backed securities (CMBS), asset-backed securities (ABS), registered corporate bonds (Reg), Rule 144A corporate bonds (144A), and municipal bonds. The footnotes report the source (academic study) for the statistics, the sample period, and the data source. "Retail" refers to trading cost estimates based on trades of less than $100,000, and "Institutional" refers to trade cost estimates on trades that exceed $1 million. Data sources are Trade Reporting and Compliance Engine (TRACE) for Agency MBS, CMBS, ABS, and corporate bonds; Municipal Securities Rule Making Board's EMMA database for municipal bonds, and interdealer broker (IDB) platforms GovPX and BrokerTec for Treasury bonds. NAIC stands for National Association of Insurance Commissioners. The market structure of the trading platforms are identified using the following superscripts in the table: x refers to the electronic limit order book IDB platform, y refers to the hybrid voice and electronic IDB platform, and z refers to request-for-quote (RFQ) platforms.

Type of Bond	Data Source	Coverage Begins	Daily Trading Volume ($B, 2017)[a]	Average Trade Size ($M)	Customer/ Total Trading, %	Customer Trading Costs, Basis Points	Electronic Trading Platforms
Treasury	GovPX	1991	505	2-year: 28[b] 5-year: 12 10-year: 10	50	2-year: 1[b] 5-year: 1 10-year: 2	BrokerTec[x] eSpeed[x]
	BrokerTec	2001					
Agency MBS	TRACE	2011	209	TBA: 33[c] MBS: 6	TBA: 52[c] SP: 80	TBA: 2[d] MBS: 80	BrokerTec[x] Tradeweb[x,y]
CMBS	TRACE	2011	3	Reg: 18[e] 144A: 47	84[d]	Reg: 53[e] 144A: 72	Tradeweb[y]
ABS	TRACE	2011	1	Reg: 8[e] 144A: 19	80[e]	Reg: 48[e] 144A: 0.44	Tradeweb[y]
Corporate	TRACE NAIC	2002 1995	31	1.2[f]	70[f]	Retail: 124[f] Institution: 36	Market Axess[z]
Municipal	MSRB	1997	11	0.41[g]	70[g]	Retail: 75[g] Institution: 20	Municenter[x]

[a] Securities Industry and Financial Markets Association (SIFMA) Fact Book 2018, p. 34 (available at https://www.sifma.org/resources/research/sifma-fact-book-2018/).
[b] Adrian, Fleming, and Vogt (2017). Sample period: 2017. BrokerTec IDB transactions data.
[c] Gao, Schultz, and Song (2017). Sample period: May 2011–Apr. 2013. TRACE data.
[d] Bessembinder, Maxwell, and Venkataraman (2013), Table 7. Sample period: May 2011–Jan. 2013. TRACE data.
[e] Hollifield, Neklyudov, and Spatt (2017), Table 2. Sample period: May 2011–Feb. 2012. TRACE data.
[f] Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018), Table 3. Sample period: Apr. 2014–Oct. 2016. TRACE data.
[g] Municipal Securities Rulemaking Board (MSRB) 2017 Fact Book (available at http://www.msrb.org/~/media/Files/Resources/MSRB-Fact-Book-2017.ashx?la=en); Wu (2018). Sample period: 2017. MSRB data.

indicator for dealer–customer trades.[10] An enhanced version of the corporate bond TRACE data is now available from FINRA for academic research and includes information on masked dealer IDs and actual transaction size. The enhanced TRACE data also include trades reported to FINRA but not disseminated to the public (e.g., trades in nonregistered "144A" securities that were completed before July 2014). Beginning July 2017, dealers are required to report both dealer–customer and interdealer trades in Treasury bonds to TRACE for regulatory analysis, but the data are not yet available to the public. In addition, data on insurance company bond transactions are available beginning 1995 from the National Association of Insurance Commissioners (NAIC). Data on interdealer trades for

[10]FINRA rules on the requisite timing of trade reports for bond categories are available at http://www.finra.org/industry/trace-reporting-timeframes. For large transactions, the trade size that is disseminated to the public is capped to allow dealers the opportunity to unwind inventory positions. For example, trade size is provided for investment grade and high-yield corporate bonds if the par value transacted does not exceed $5 million and $1 million, respectively; otherwise an indicator variable ("5MM+" and "1MM+," respectively) denotes a trade of more than the capped size.

Treasury securities completed on IDB platforms are available beginning 1991 from GovPX, and after 2001, from eSpeed and BrokerTec.

Information on bond characteristics (e.g., issue size, offering date, maturity date, credit rating, and issuer industry) is available for non-Treasury securities from Mergent Fixed Income Securities Database (FISD) or Bloomberg, and for Treasury securities from the U.S. Treasury (https://www.treasurydirect.gov/). Data on investor flows into or out of bond mutual funds are available from the Investment Company Institute. Data on bond mutual fund holdings are available from the Center for Research in Security Prices (CRSP) Mutual Fund database, Morningstar database, and Thomas Lipper eMaxx database, and for individual Treasury securities from the U.S. Treasury. Securities lending data for bonds are available from Markit Securities Finance database, and previously from Data Explorers.

IV. Trading Activity in Bond Markets

A. Treasury Bonds

According to a 2017 Treasury report, the market for U.S. Treasury bonds is among the largest and most liquid markets in the world (https://www.treasury.gov/press-center/press-releases/Documents/A-Financial-System-Capital-Markets-FINAL-FINAL.pdf). Between Aug. 1, 2017 and July 31, 2018 (the first year dealers were required to report Treasury transactions to FINRA), daily Treasury trading volume averaged $574 billion (http://libertystreeteconomics.newyorkfed.org/2018/09/unlocking-the-treasury-market-through-trace.html).[11] Transactions between dealers and customers account for about half ($269 billion) of Treasury activity. Intermediation in the dealer-to-customer market is provided by 23 primary government bond dealers, as designated by the Federal Reserve Bank of New York. Trades among dealers have historically been intermediated by IDBs. In recent years, approximately 70% of interdealer activity occurs on electronic IDB platforms, and the remainder on voice and manual screen platforms. According to the 2015 Joint Staff Report on the U.S. Treasury Market (https://www.treasury.gov/press-center/press-releases/Documents/Joint_Staff_Report_Treasury_10-15-2015.pdf), nonbank principal trading firms that implement HFT strategies account for a larger share of trading activity (62%) than primary bond dealers (33%) on electronic IDB platforms.[12] Treasury IDB trading activity is concentrated in on-the-run securities, that is, the most recently issued notes or bonds of a particular maturity. In terms of 2017 daily trading volume, the 5-year note is the most active on-the-run security ($48 billion par), followed by the 10-year ($40 billion par) and 2-year ($18 billion par) notes. Trading activity in off-the-run issues is weighted toward shorter maturity bonds and is more likely to be intermediated on voice and manual IDB platforms. Graphs A and B of Figure 2 displays average daily trading volume and average trade size for on-the-run Treasury securities between 1991 and 2017.

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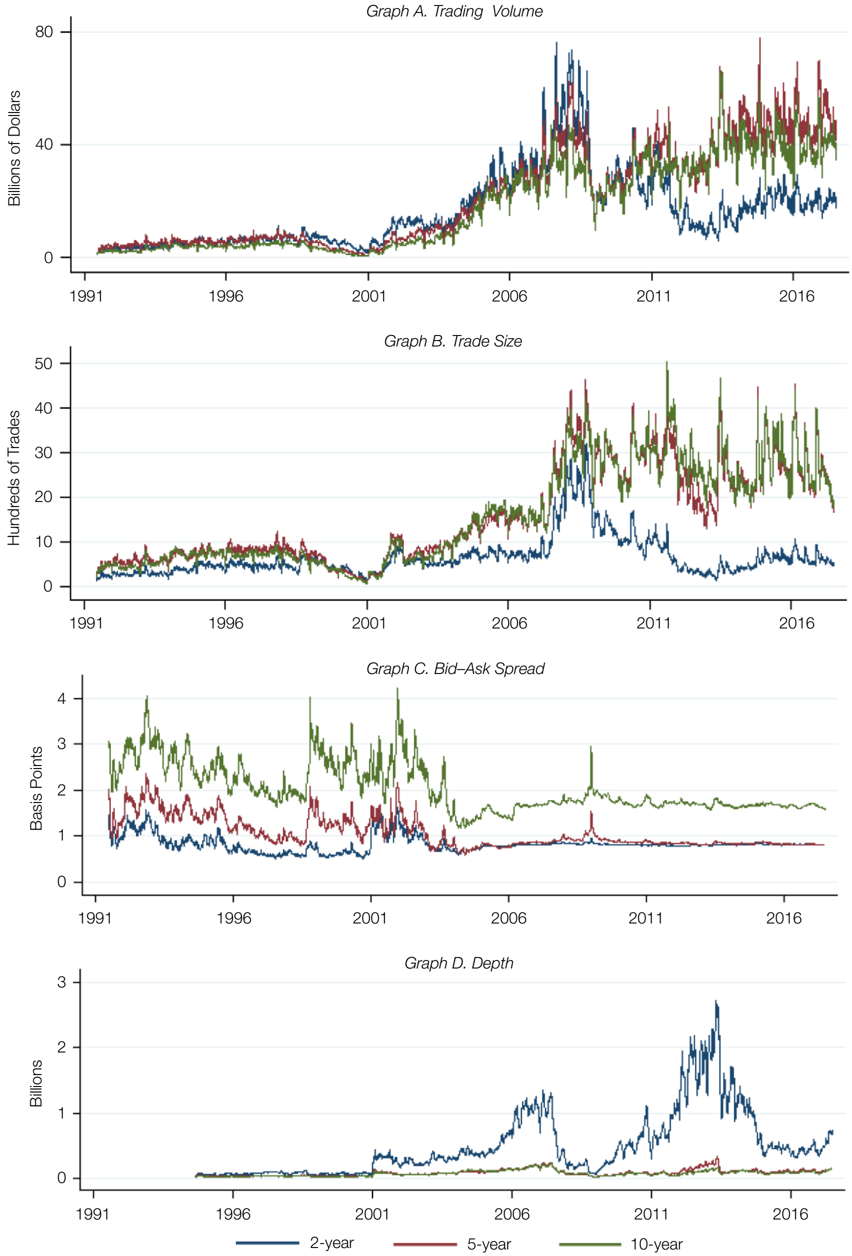
[11] We thank Michael Fleming and BrokerTec for providing 2017 IDB Treasury trading data.

[12] Principal trading firms account for 60% to 70% of the trading volume in Treasury bonds and approximately 50% of the trading volume in Treasury futures in recent years. The firms participate as short-term liquidity providers and rarely carry overnight inventory positions.

FIGURE 2

Trading Activity, Bid–Ask Spreads, and Depth in the U.S. Treasury Bond Market (1991–2017)

Figure 2 plots trading volume (Graph A), average trade size (Graph B), average bid–ask spread (Graph C), and average order book depth at the inside spread (bid and offer side) (Graph D) in the U.S. Treasury market. The data sources are the interdealer broker (IDB) trading platform GovPX and BrokerTec, estimated by day from June 17, 1991 to June 30, 2017. Plotted lines are exponentially weighted moving averages. This figure was reproduced with permission from Adrian, Fleming, and Vogt (2017).



Macroeconomic announcements are an important source of uncertainty for the valuation of Treasury instruments. Fleming and Remolona (1999) show that trading activity and bid–ask spreads adjust to scheduled macroeconomic announcements in stages (see Balduzzi, Elton, and Green (2001), Green (2004), among others, for related evidence). Before an announcement, the sensitivity of prices to order flow is lower than normal, suggesting an absence of information leakage. The announcement induces a sharp and nearly instantaneous price change accompanied by a reduction in trading volume and an increase in bid–ask spreads. These results are consistent with French and Roll's (1986) assertion (page 9) that public information "affects prices before anyone can trade on it" as well as models of inventory risk (e.g., Ho and Stoll (1983)), where dealers set wider bid–ask spreads when volatility is high. In the seconds after announcements, trading volume increases, as do price volatility and the price impact of trades. These patterns support theoretical predictions (e.g., Kim and Verrecchia (1991), (1994)) regarding informed traders' ability to quickly interpret the valuation implications of macro announcements. In the 5–15 minutes after announcement, the market is characterized by high liquidity and smaller price effects of trades, consistent with the interpretation that uninformed traders participate in portfolio rebalancing trades in the wake of these announcements.

Brandt and Kavajecz (2004) document substantial variation in yields on Treasury instruments, even in the absence of macroeconomic or other news releases. They find that order-flow imbalances account for 26% of yield variation on days with no news, implying that the trading process itself contains information for price discovery in government bonds. This finding parallels the French and Roll (1986) result that the trading process provides substantial information for equity pricing, even absent fundamental news.

B. Structured Bonds

The most actively traded structured securities are TBAs, which are forward contracts that allow the seller to deliver any agency MBS that meets agreed-upon criteria based on coupon, maturity, and issuer, on the settlement date.[13] The buyer and seller negotiate the trade price and MBS face value to be transacted. The TBA price reflects the cheapest-to-deliver MBS that fulfills the terms of the TBA trade, although traders do not make or take delivery in most cases. The TBA market is used by banks and other intermediaries to hedge mortgages that they originate and by investors that buy and sell already-issued MBS. Gao, Schultz, and Song (2017) report that the average dealer-to-customer transaction size of outright TBA trades during their May 2011 to Apr. 2013 sample period is $32.6 million, and about 37% of trades between dealers and customers exceeds $10 million. Individual structured MBS bonds trade in the "specified pool" (SP) market, where buyers and sellers agree to exchange a particular bond. The average customer transaction size of SP trades during the same period is $6.5 million, and 10.7% of these transactions are for $10 million or more.

[13]MBS are pass-through securities in which interest and principal payments on the underlying mortgages are passed on to bond investors. A basic pool of assets may have more than 100 securities or tranches, each with a unique payoff structure, with many of these issues being very small.

Bessembinder et al. (2013) study trading in structured products from May 2011 to Jan. 2013. Notably, they report that most outstanding structured bonds do not trade at all during their sample. They report that agency MBS are more likely to trade than structured bonds issued by private entities, such as commercial mortgage-backed securities (CMBS) or ABS, which are subject to credit risk. Trading activity in both the MBS and ABS markets is negatively related to bond age, credit risk, and interest rate risk and positively related to issue size.[14] The study also finds that dealer-to-customer trades represent almost 80% of trading volume for individual structured bonds, compared to 52% for the TBA market. Gao et al. (2017) attribute the high percentage of TBA interdealer trades to hedging activities of dealers, who also hold positions in the SPs that are eligible for TBA delivery.

C. Corporate Bonds

Trading activity in corporate debt is fragmented because an issuer often has multiple bond issues outstanding. Because each involves a unique set of promised payments, bond issues are not fungible, and each trades separately. As of Dec. 2017, firms in the Standard & Poor's (S&P) 500 index had 11,990 outstanding bond CUSIPs, whereas firms in the Russell 1000 index had 13,083 outstanding bond CUSIPs. Mizrach (2016) finds that trades for 33,945 distinct bond CUSIPs are reported in the TRACE database during the first 9 months of 2015. More than 90% of TRACE-reported bonds are rated investment grade, and the most common credit rating is BBB. A majority of corporate securities are privately placed structured bonds that do not trade actively.

Bessembinder et al. (2018) report that aggregate corporate bond trading activity, measured by either number of trades or transaction volume, surges over their 2006–2016 sample period. This increase in trading activity is accompanied by even more rapid growth in corporate bond issuance. Annual trading activity relative to the amount of corporate bonds outstanding (i.e., turnover) generally trends downward, from 94% in 2006 to 62% in 2015. The share of overall trading volume increases for investment-grade bond issues and large-issue-size bonds during that period, as does the share of transactions that are likely to be facilitated by electronic venues.

The distribution of the number of days that a corporate bond issue trades in a year is highly skewed. It is reported that 9.3% of TRACE bonds never trade during 2016, 39% trade on 5 or fewer days, and only 1.5% trade every day.[15] Among bonds with issue size greater than $1 billion, the average number of days in a year with any trading is 179 for investment-grade bonds and 150 for high-yield bonds. As a consequence, estimates (e.g., of transactions costs) obtained by weighting observations across observed trades largely represent outcomes in the more active segments of the corporate bond market.

[14] See also Friewald, Jankowitsch, and Subrahmanyam (2014), Atanasov and Merrick (2012), and Hollifield et al. (2017), each of which studies structured product trading.

[15] See the Citi report, "Developments in Credit Market Liquidity," Jan. 11, 2018, presented at the SEC's Fixed-Income Market Structure Advisory Committee (FIMSAC) meeting (https://www.sec.gov/spotlight/fixed-income-advisory-committee/citi-developments-in-credit-market-liquidity-fimsa-011118.pdf).

Institutional-sized trades (greater than $1 million) account for most of the dollar volume of trades, in particular, 88% of customer trading volume between 2014 and 2016 (Bessembinder et al. (2018)). Retail-size trades (less than $100,000) account for between 60% and 70% of reported customer transactions, but only 2% of customer trading volume during the same period. Average trade size has decreased over the last decade, from $2 million in 2006–2007 to $1.21 million in 2014–2016.[16] The decrease in average trade size could reflect higher participation by retail investors, increased use of electronic venues that typically execute smaller trades, and/or difficulty in locating counterparties for large trades that are desired.

Informed traders are active in corporate bonds, as evidenced by the finding in Wei and Zhou (2016) that abnormal bond trading activity before corporate earnings announcements predicts both the direction of earnings surprises and the post-announcement bond returns. Kedia and Zhou (2014) present evidence of an increase in trading activity and abnormal returns in the bonds of target companies before acquisition announcements. Das, Kalimipalli, and Nayak (2014) report that large institutional traders shift from corporate bonds to credit default swap (CDS) trading after the introduction of the latter, resulting in reduced bond price efficiency.

Informed trading may occur simultaneously in equity, debt, and derivative instruments of a firm. Back and Crotty (2015) examine the price impact of order flows in the stock and bond markets. When investors' private information involves asset mean value, Back and Crotty's model predicts that the cross-market price impacts are positive, and when investor's information involves asset risk, the cross-market price impacts are negative. They show empirically that cross-market price impacts are positive, implying that private information primarily involves mean asset values, and that both cross-market and own-market price impact estimates are larger for firms with high-yield debt than for firms with investment-grade debt.

Asquith, Au, Covert, and Pathak (2013) study corporate bond lending by one major depository institution, reporting that the cost of borrowing bonds is between 10 bps and 20 bps (comparable to the cost of borrowing stocks) and declines during their 2004–2007 sample period. In contrast to results obtained for equity short selling, Asquith et al. report that bond short selling does not forecast price changes over the following month.

Two recent studies conclude that short selling predicts bond returns in scenarios where private information is more likely. Hendershott, Kozhan, and Raman (2019), who study data during 2006–2011, report that short selling predicts bond returns in high-yield corporate bonds. They also show that short positions on average increase following periods of buying order imbalances, which is consistent with short sellers "leaning against the wind" in a de facto market-making role. Using bond lending data over 2006 to 2015, Anderson, Henderson, and Pearson (2018) also find that proxies for short-sale constraints predict negative 3-month abnormal returns. The study concludes that information is incorporated more slowly in bonds than in equities because of lower trading frequency and liquidity.

[16]By comparison, the sizes of equity trades also declined dramatically over the years, in part because of Regulation NMS, and in an earlier era, because of decimalization.

On balance, the shorting of fixed-income instruments comprises a promising area for future research.

The literature finds mixed evidence regarding the relative information efficiency of stock versus corporate bond markets. Kwan (1996) and Downing, Underwood, and Xing (2009) report that stock prices lead corporate bond prices in incorporating firm-specific information, whereas Hotchkiss and Ronen (2002) and Ronen and Zhou (2013) report that corporate bond markets are as informationally efficient as stock markets. Back and Crotty (2015) find that the equity market leads the bond market for the portion of returns that are not explained by order flows.

D. Municipal Bonds

Trading activity in municipal bonds is highly fragmented, as more than 50,000 issuers, including state and local governments, towns, cities, and counties, have issued over 1.5 million distinct bonds, with an outstanding principal value of $3.9 trillion at the end of 2017.[17] Municipal bonds are issued in series, with larger issuances consisting of several smaller bonds of differing maturity. Municipal bond issuers typically disclose financial information at the time of bond issue, but they are not required to make periodic financial disclosures (see Downing and Zhang (2004)). Investor ownership tends to be geographically concentrated, as many jurisdictions exempt only own-state issues from state and local income taxes. Furthermore, limited disclosure may result in bonds being disproportionately held by more knowledgeable local investors.

Most municipal bonds have had a credit rating of AA or better, reflecting the issuers' tax authority and, before the financial crisis, the widespread use of credit enhancement via insurance.[18] The use of municipal bond insurance comprises an interesting puzzle, as risk sharing is often viewed as a central purpose of financial markets, but it is unclear to what extent insurers have the capacity to bear capital market risks that have substantial systematic components. Indeed, the limited capacity to bear correlated risk was at the root of the failure of mortgage insurers during the financial crisis.

Chalmers et al. (2019) study MSRB data. For their most recent (2011–2012) subperiod, they report that transactions of less than $25,000 account for more than half of the trades, and those less than $100,000 account for nearly 99% of trades, reflecting that individual investors hold the majority of outstanding municipal bonds. Trades greater than $1 million account for 1.5% of transactions but represent 45% of volume traded. Wu (2018) reports that interdealer trades account for 28% to 37% of all par value traded between 2005 and 2017. The volume of customer-buy transactions significantly exceeds the volume of customer-sell transactions, indicating that investors frequently hold municipal

[17] Studies of municipal bond trading include Downing and Zhang (2004), Edwards et al. (2007), Green, Hollifield, and Schürhoff (2007a), (2007b), Green, Li, and Schürhoff (2010), Schultz (2012), Chalmers, Liu, and Wang (2019), and Wu (2018).

[18] One potential policy innovation is to introduce a forward market for municipal bonds, similar to the TBA market for agency MBS. For municipals, the basis risk is due to tax status and default risk, whereas for MBS, the basis risk is due to prepayment and default risk.

bonds until maturity. However, the difference in buy versus sell volume has declined in recent years.

According to 2018 MSRB statistics, electronic platforms account for 59% of all interdealer trading in municipal bonds (https://emma.msrb.org/MarketActivity/ViewStatistics.aspx). The states with the highest secondary market trading volume in the municipal bond market are California (14.6%), Texas (13.8%), New York (9.3%), and Illinois (9.1%). Less than 1% of outstanding municipal bonds trade on a typical day, and less than 15% of the outstanding bonds trade in a typical month. Trading activity is highest during the month of the bond issuance and drops off sharply by the second month.

V. Trading Costs in Fixed-Income Markets

The estimation of trading costs in bond markets is challenging for several reasons. With the exception of Treasury securities, dealers do not post firm bid and ask quotes, and other indications of trading interest, such as indicative quotes and limit orders, are not widely disseminated and may not be available to researchers. This implies that simple measures often used in equity markets, such as quoted spreads (the difference between the bid and ask quote) or effective spreads (the difference between the trade price and the quote midpoint), cannot be readily implemented in the majority of bond markets.

Researchers have estimated bond market liquidity using methods that rely on transaction price data alone. For example, Bao, Pan, and Wang (2011) estimate illiquidity in bond markets using the return reversal measure of Roll (1984), whereas Chen, Lesmond, and Wei (2007) focus on the percentage of trading days with zero returns, taken to be indicative of a lack of trading due to high costs. Schestag, Schuster, and Uhrig-Homburg (2016) study several bond liquidity measures including i) trade price reversal measures such as Roll's (1984) estimator, Hasbrouck's (2009) Gibbs sampler, and Pastor and Stambaugh's (2003) measure; ii) price impact measures such as Hasbrouck's (2009) lambda and Amihud's (2002) measure; and iii) Corwin and Schultz's (2012) high-to-low price ratio measure, which exploits that daily high (low) prices are most often buy (sell) orders. Jankowitsch, Nashikkar, and Subrahmanyam (2011) and Feldhutter (2012), among others, use the dispersion in bond transaction prices to indirectly measure customer search costs attributable to limited pre-trade transparency.

A significant challenge in using transaction prices to estimate trading costs arises from the infrequent trading activity in the majority of corporate bonds, implying that there is potential for substantial information arrival between adjacent transactions, which introduce noise in the empirical estimates. In the absence of quotation data, an additional challenge arises in the selection of a benchmark price for measuring trading costs.[19]

The most frequently implemented approaches to estimating trading costs in bond markets are the dealer round-trip (DRT) cost method and indicator-variable regression models. These methods take advantage of the fact that bond databases

[19]For example, Hendershott and Madhavan (2015) use the last interdealer trade in the bond as the benchmark price. However, this benchmark contains noise, as interdealer trades cannot readily be classified as buyer or seller initiated.

such as TRACE identify interdealer versus dealer–customer trades, and for customer trades, whether the customer was the buyer or the seller in the transaction. However, these measures rely on completed trades and thus do not account for trades that were desired but not completed because of a lack of liquidity. Furthermore, transaction-based estimates are inherently biased toward bonds and periods with frequent trading, which tends to occur when liquidity is plentiful.

A. DRT Cost

The DRT cost measures the difference between the average dealer sale price and the average dealer purchase price in dealer-to-customer transactions for a given bond during a specified window. The interval is most frequently 1 day (e.g., Green et al. (2007b)), though some studies examine shorter (15 minutes in Feldhutter (2012)) or longer (5 days in Goldstein, Hotchkiss, and Sirri (2007)) windows.[20] Earlier studies calculate the average sale and purchase price across all dealers (e.g., Hong and Warga (2000), Chakravarty and Sarkar (2003)), whereas studies using enhanced TRACE data with masked dealer identifiers calculate the average prices on an individual dealer basis (e.g., Goldstein et al. (2007)).[21] The advantages of the DRT measure are that i) it is simple to interpret as an average realized bid–ask spread and ii) it does not rely on any model assumptions. A limitation is that the measure does not capture transactions that are not offset by opposite-direction trades within the observation window, which limits the amount of usable data and makes the method difficult to implement for bonds that trade infrequently.

B. Indicator-Variable Regression Model of Trading Costs

The indicator-variable regression model was first used to estimate trading costs in equity markets (see Huang and Stoll (1997), Madhavan, Richardson, and Roomans (1997)) but has since been adapted to bond markets.[22] The model presumes that the transaction price for a customer buy (sell) is the intrinsic value of the bond at the time of transaction, plus (minus) half the bid–ask spread. The spread reflects dealers' inventory, adverse selection, and order-processing costs, and, potentially, monopoly power over less sophisticated customers.

Specifically, trading cost estimates can be obtained by regressions of ΔP_{st}, the percentage change in the trade price for a given bond between an observed trade at time s to the next observed trade at time t, on $\Delta Q_{st} = Q_t - Q_s$, where Q_s

[20]In fact, Hollifield et al. (2017) discard intermediation chains that take more than 15 days to complete, controlling for valuation changes between the execution times by using several marketwide control variables, and Goldstein and Hotchkiss (2020) examine sales within 60 days of the dealer's buy order.

[21]Studies that calculate DRT costs using NAIC insurance data include Chakravarty and Sarkar (2003) and Hong and Warga (2000), MSRB municipal bonds data include Green et al. (2007b), TRACE corporate bonds data include Goldstein et al. (2007) and Feldhutter (2012), and TRACE structured bonds data include Hollifield et al. (2017).

[22]For applications in the bond market, see Schultz (2001), Bessembinder, Maxwell, and Venkataraman (2006), Harris and Piwowar (2006), and Edwards et al. (2007). Some differences in approaches exist across the studies. Schultz uses bid quotes as of end of prior month from FISD with adjustments for change in interest rates. Harris and Piwowar present a time-series trading cost model that incorporates interdealer transactions.

and Q_t are indicator variables equal to 1 for customer buys and −1 for customer sells at times s and t. The resulting slope coefficient estimates the effective one-way trade execution cost and can be interpreted as half the difference between the price at which dealers will sell a bond to a customer and the price at which they will purchase the bond from a customer. The analysis is typically implemented using trades between dealers and customers. To account for information flow between adjacent transactions, the model can incorporate additional measures of observable public information, such as changes in Treasury interest rates, stock returns, market volatility, and so on, that affect the intrinsic bond value. A key advantage is that the method can include all bond transactions and, using pooled estimation, can be implemented for subsets of bonds with modest trading activity. A limitation is that the impact of public information on intrinsic bond values could differ across bonds, which might introduce measurement errors in pooled estimation.

C. Estimates of Trading Costs in Bond Markets

The secondary market for Treasury bonds is extremely liquid, with an estimated interdealer bid–ask spread on the BrokerTec IDB during 2017 of about 1 bp.[23] The average quoted depth at the best price on the BrokerTec limit order book averaged \$645 million for the 2-year note, \$125 million for the 5-year note, and \$109 million for the 10-year note. The market is even deeper when considering the hidden portion of iceberg orders and the "work-up" feature that allows participants to negotiate to expand the trade size after agreeing on a price.[24] Spreads are higher for longer duration bonds and smaller for larger issue size and recently issued bonds. Graphs C and D of Figure 2 display average daily bid–ask spreads and depth in the IDB market for on-the-run Treasury securities between 1991 and 2017. Bid–ask spreads exhibit a spike during the peak of the financial crisis but are relatively stable over the last decade.

In the structured bond market, Bessembinder et al. (2013) report an average customer round-trip trade execution cost between 2011 and 2013 of 0.48%. Trading cost estimates decline with trade size, averaging 1.65% for small (less than \$100,000), 0.48% for medium (between \$100,000 and \$1 million), and only 0.10% for large (greater than \$1 million) trades. Trade execution costs vary substantially across types of structured bonds, with higher cost estimates observed for products of smaller issue size. The lowest trading costs are estimated for TBA securities (0.02%), whereas the highest cost estimates are for agency collateralized mortgage obligations (CMOs, 1.5%). Average customer trading cost estimates are 0.80% for agency MBS, 0.24% for CMBS, and 0.48% for ABS.

[23]We thank Michael Fleming for providing BrokerTec statistics for 2017. Additional description of BrokerTec is provided by Fleming, Mizrach, and Nguyen (2018).

[24]The importance of a workup mechanism in Treasuries in which additional size can be transacted immediately after a transaction at the specified price is highlighted by Boni and Leach (2004). Fleming and Nguyen (2020), Fleming, Schaumburg, and Yang (2015), and Schaumburg and Yang (2016). Duffie and Zhu (2017) show that such a workup or dark pool mechanism can limit the allocative inefficiency that may result from larger transactions, but because of adverse selection about the order imbalances of other investors would only be used by investors with relatively large position imbalances.

For agency CMOs, Hollifield et al. (2017) find that 144A instruments have smaller spreads than registered instruments, which may reflect the greater bargaining power of the relatively more sophisticated investors in 144A bonds as compared to investors in registered bonds. Friewald, Jankowitsch, and Subrahmanyam (2012) report that trading costs for structured bonds are lower if they are traded in institutional size, are issued by a federal authority, or have low credit risk. Vickery and Wright (2013) and Gao et al. (2017) find that mortgage bonds that are eligible for delivery in the TBA market are cheaper to trade than TBA-ineligible mortgage bonds, reflecting that the TBA market allows dealers to effectively hedge TBA-eligible MBS positions.

Schultz (2001) relies on the NAIC database to report the first large-sample estimates of corporate bond trading costs, documenting that average trading costs are large as compared to equities, and that costs for large institutional trades exceed those that are small. Bessembinder et al. (2018) provide what may be the broadest study of corporate bond trading, studying TRACE data from 2006 to 2016.[25] For the recent 2014–2016 period, they estimate average round-trip trading costs of 0.84%.[26] Trading cost estimates decrease with trade size, averaging 1.25% for trades less than $100,000, 0.58% for trades between $100,000 and $1 million, 0.40% for trades between $1 million and $10 million, and 0.32% for block trades that exceed $10 million. Graph A of Figure 3 plots estimated average one-way trading costs over 2006–2016. Although trading costs temporarily increase during the financial crisis, average cost estimates at the end of the sample period are nearly equal to those at the beginning. Edwards, Harris, and Piwowar (2007) report that corporate bond trading costs are lower for corporate bonds with larger issue size, with better credit quality, for younger (more recently issued) bonds and those closer to maturity, for simpler bonds without options, and for bonds issued by private issuers, Rule 144a issues, and foreign issuers.

Bessembinder et al. (2018) report that the majority of corporate bond transactions, more than 90% each year between 2006 and 2016, are facilitated by dealers as "principal" trades, where the dealer commits capital to take bonds into inventory. Several studies (see Harris (2015), Choi and Huh (2017), and Schultz (2017)) report that the incidence of agency trading, where a dealer facilitates trades between customers without taking ownership or where the dealer briefly owns the bond before completing a previously arranged transfer to another customer, has increased in recent years. Choi and Huh (2017) report that trading costs for transactions where dealers continue to commit capital have increased in recent years.

Harris and Piwowar (2006) estimate trading costs for municipal bonds during the earlier Nov. 1999–Oct. 2000 period. They report higher trading cost

[25]The SAS programs used by Bessembinder et al. (2018) to read and clean the enhanced corporate bond TRACE data, estimate trading costs using indicator regression model, and calculate dealer capital commitments are available at https://people.smu.edu/kumar/tracecorporatebonds/.

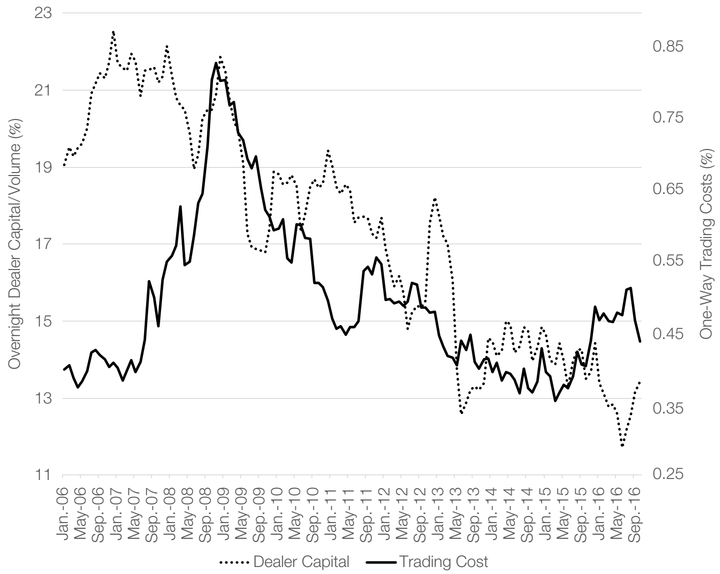
[26]See Edwards et al. (2007) for cross-sectional analysis of trading costs. Time-series analysis of trading costs is presented in Bessembinder et al. (2018), Bao et al. (2018), Dick-Neilsen and Rossi (2019), Schultz (2017), Trebbi and Xiao (2019), and Anderson and Stulz (2017), among others. For a sample of actively traded corporate bonds, Schestag et al. (2016) find that trading cost measures using intraday data are correlated with each other, and that low-frequency measures using daily data are representative of trading costs based on intraday data.

FIGURE 3

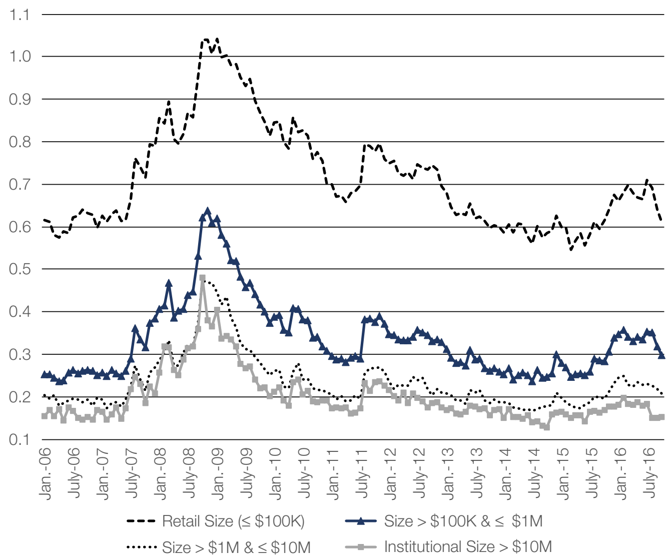
Trading Costs and Dealer Capital Commitment in the U.S. Corporate Bond Market

Figure 3 shows estimated trade execution costs paid by customers in customer-to-dealer principal trades in the corporate bond market from Jan. 2006 to Oct. 2016. In Graph A, transaction costs (one-way) are estimated following the indicator regression model implemented by Bessembinder, Maxwell, and Venkataraman (2006) using enhanced Trade Reporting and Compliance Engine (TRACE) data. Overnight dealer capital shows the 6-month moving average aggregate overnight capital scaled by volume for the top 70% dealers examined by Bessembinder, Jacobsen, Maxwell, and Venkataraman (2018). Graph B shows trade execution costs in customer-to-dealer principal trades for four trade size categories: small trades, which are less than or equal to $100,000; medium trades, which are greater than $100,000 and less than or equal to $1 million; large trades, which are greater than $1 million and less than or equal to $10 million; and institutional trades, which are greater than $10 million.

Graph A. Customer Trading Costs and Dealer Capital Corporate Bond Market (2006–2016)



Graph B. Monthly Corporate Bond Trading Costs (%) on Customer Transaction by Trade Size



estimates for municipal bonds of lower credit quality, smaller issue size, and with complex features. Trading cost estimates are also lower for younger bonds and those near maturity. Wu (2018) studies DRT trading costs for municipal bonds using MSRB transactions data between 2005 and 2018, reporting average cost estimates of 0.90% for retail-size trades (par value less than $10,000) versus 0.15% for institutional-size trades (par value exceeds $1 million) in Apr. 2018. Figure 4 displays annual estimates of round-trip municipal bond trading costs compiled by Wu. Estimated trading costs decline, particularly for small trades, between 2009 and 2018, whereas costs increase for all trade size categories during the financial crisis.[27] Although the trading cost differential between retail and institutional trades has narrowed in recent years, institutional-size trades continue to obtain lower cost executions as compared to retail-size trades in municipal bond markets.

These estimates of trade execution costs focus on the direct cost of trades that were successfully completed. As such, they do not account for the potential delays in completing transactions or costs associated with trades that were desired but not completed. Unfortunately, proprietary data sets from buy-side bond institutions that include information on execution delays and fill rates are not available to researchers.[28] To obtain additional perspective, researchers have studied dealers' capital commitment (i.e., the extent to which dealers use their own capital to absorb imbalances in customer order flow). Capital commitment is particularly important in markets (e.g., corporate bonds) where customers arrive infrequently and search costs are large.

It is possible to estimate dealers' capital commitment using the enhanced TRACE database that includes masked individual dealer identities. Bessembinder et al. (2018) and Bao et al. (2018) both report that although average transaction costs have not increased in recent years, dealers' capital commitment has declined markedly (see Graph A of Figure 3). The decreases in capital commitment are attributable to bank-affiliated dealers, whereas nonbank dealers increase their capital commitment, albeit from low initial levels. Each study concludes that post-crisis banking regulation, including the Volcker Rule (which restricts proprietary trading by banks), has likely contributed to the decline in bank-affiliated dealer capital commitment, and has accelerated the increase in capital commitment by nonbank dealers because of their equilibrium response. Goldstein and Hotchkiss (2020) show that dealers are particularly hesitant to commit capital to accommodate larger trades in riskier bonds. Duffie (2018) and Adrian, Fleming, Shachar, and Vogt (2017) observe that Basel 2.5 and Basel III banking regulations have increased the required capital (i.e., equity) requirements for inventory holdings of credit products with higher default risk. This has led to an increase in dealers' inventory funding costs, particularly for corporate bonds and credit derivatives, and likely has contributed to the decline in dealer capital committed to market making.

A striking pattern observed in most bond markets is that smaller transactions, which are more likely to originate from retail investors, are more expensive

[27]However, the reasons for this decline are the source of some debate (see https://www.bondbuyer.com/news/bdas-problems-with-msrb-spreads-study).

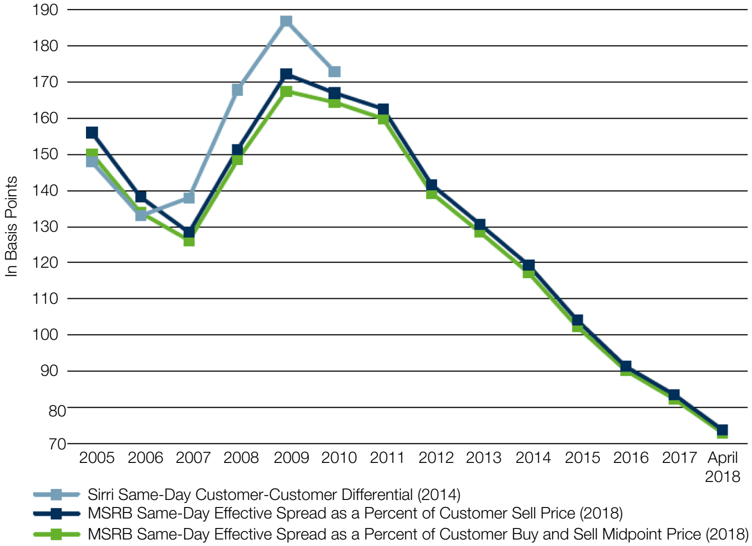
[28]In contrast, data on institutional investors' actual and desired equity market transactions are compiled by Abel Noser (a consulting firm that works with institutional investors to monitor execution costs) (see, e.g., Puckett and Yan (2011), Anand, Irvine, Puckett, and Venkataraman (2012)).

FIGURE 4

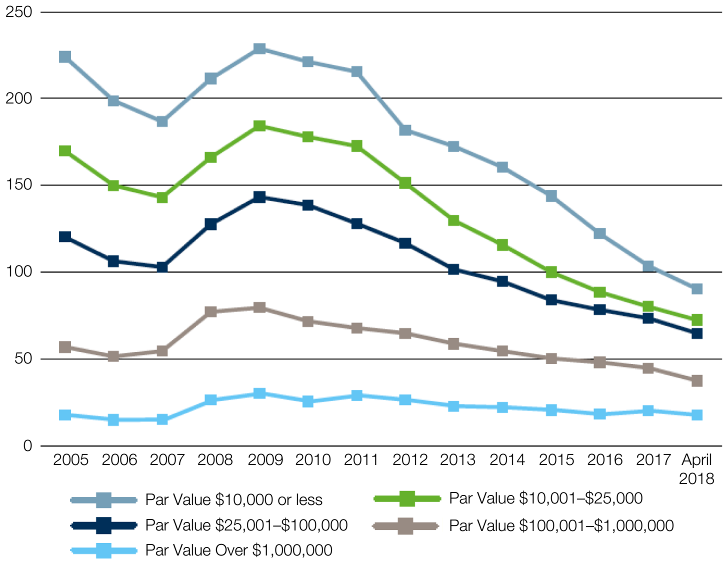
Trading Costs in the U.S. Municipal Bond Market (2005–2018)

Graph A of Figure 4 plots the dealer round-trip effective spread trading costs measured as a percentage of the midpoint between average customer buy and sell prices (green line) and as a percentage of customer sell price (blue line) for all customer-to-dealer trades, and for five transaction size groups for municipal bonds between 2005 to 2018 using the Municipal Securities Rulemaking Board (MSRB) database, as reported in Wu (2018). The light blue line reports the effective spread estimates from Sirri (2014). Graph B shows the effective spread by five trade-size groups during the relevant period: less than $10,000 par value or less, $10,001–$25,000 par value, $25,001–$100,000 par value, $100,001–$1,000,000 par value, and more than $1,000,000 par value trades. This figure was reproduced with permission from Wu (2018).

Graph A. Municipal Bond Effective Spread for Customer-Buy and -Sell Trades (2005–2018)



Graph B. Municipal Bond Effective Spread for Customer-Buy and -Sell Trades by Trade Size (2005–2018)



to complete than larger transactions, which more likely originate from institutional investors. Graph B of Figure 3 displays annual estimates of customer trade execution costs in U.S. corporate bond markets, for small (less than $100,000), medium ($100,000 to $1 million), large ($1 million to $10 million), and institutional (greater than $10 million) trades. This pattern of higher percentage execution costs for small trades is the opposite of that typically observed in equity markets. It is difficult to attribute the trade size cost differential in bond markets to higher adverse selection, as institutional investors have more resources than individual investors to analyze credit risk, or to higher inventory risk, as large trades involve more dealer capital than small trades.

The explanation for differential effects of trade size on transaction costs across bond and equity markets likely lies in market structure. Equity markets are more transparent and governed by order-handling rules that require execution at the best available price, whether posted by the trading public or a dealer. The opaque and decentralized nature of the bond market involves high search costs that can place less sophisticated investors at a significant disadvantage. Duffie, Gârleanu, and Pedersen (2005) develop the seminal search and matching model of an OTC market, deriving the bid–ask spreads charged by dealers and predicting that bilaterally negotiated prices depend on the relative bargaining power of traders, whereas Green et al. (2007b) predict that fragmentation and the lack of transparency in the bond market create opportunities for dealers to exploit monopoly power over retail investors.

Although the market power hypothesis may have considerable explanatory power (especially for municipal bonds, where retail participation is especially high), it is not necessarily a complete explanation. For example, smaller trades have larger spreads than larger trades in securitized trading (e.g., Hollifield et al. (2017)), even though structured products can be purchased only by accredited investors. Furthermore, as discussed later, a similar size effect arises in the studies of Bessembinder, Maxwell, and Venkataraman (2006) and O'Hara, Wang, and Zhou (2018), even though their samples are based entirely on insurance company transactions.

D. Trading Costs and Equilibrium Asset Pricing

Trade execution costs matter not only because they measure the cost of completing trades, but also because they can affect the cost of capital for issuing entities. Amihud and Mendelson (1986) propose that expected asset returns should increase with asset illiquidity, as investors require compensation for the costs of buying and selling an asset. Amihud and Mendelson (1991) compare yields on short-term U.S. Treasury notes and Treasury bills with the same maturity. Although each instrument has identical cash flows and interest rate risk, the market for bills is substantially more liquid than the market for notes. The study finds that yields on notes are higher than those on bills, and the differential is a decreasing function of time to maturity, which supports the theoretical prediction that bond market liquidity affects the pricing of credit instruments. Similarly, Krishnamurthy (2002) attributes the yield differential between on-the-run and off-the-run Treasury bonds to liquidity.

In corporate bonds, illiquidity has been offered as an explanation for the puzzle that credit spreads (i.e., yields relative to Treasury securities) are higher than those predicted by structural models of corporate default risk. Chen et al. (2007) present evidence that bond illiquidity significantly explains variation in yield spreads across corporate bonds. Chen, Huang, Sun, Yao, and Yu (2018) find that the relation between trading costs and illiquidity in corporate bonds is concave, and they attribute the nonlinearity to clientele effects where investors with longer horizons hold less liquid bonds, as also predicted by Amihud and Mendelson (1986).

Friewald et al. (2012) and Dick-Nielsen, Feldhutter, and Lando (2012) find that the impact of liquidity on bond pricing is significantly larger both during crisis periods and for non-investment-grade bonds. Bao, Pan, and Wang (2011) report that changes in marketwide illiquidity explains a substantial portion of the time-series variation in yield spreads of high-rated (AAA to A) bonds. They conclude that illiquidity risk is more important in explaining the increase in corporate yield spreads during the 2008 financial crisis than is credit risk. Friewald and Nagler (2020) find that time-varying measures of inventory, search, and bargaining frictions in the corporate bond market explain the systematic component of yield spread changes. Lin, Wang, and Wu (2011) report that the sensitivity of corporate bond returns to fluctuations in an aggregate corporate bond liquidity factor helps explain corporate bond yields, implying that systematic liquidity risk is relevant for bond valuation. However, Bongaerts, de Jong, and Driessen (2017) argue that although exposure to the equity market price and liquidity risk affect corporate bond yields, the effect of exposure to a corporate bond liquidity factor is economically negligible.

VI. Relevance of Dealer Networks

A. Dealer Networks and Client Costs

Researchers in recent years have increasingly focused on the fact that dealer markets, including those that dominate fixed-income trading, exhibit a rich network structure. The dealer network in many bond markets exhibits a core–periphery structure. The central or core dealers are highly interconnected, participate in intermediation chains that can involve multiple dealers, and account for a high proportion of trading activity. For example, 10–12 dealers account for 70% of trading volume in corporate bonds between 2006 and 2016 (see Bessembinder et al. (2018)). Peripheral dealers are sparsely connected and execute relatively few transactions.

An interesting way to cast the dealer network is that it arises in response to heterogeneity in dealer valuations and/or costs.[29] This has been a central theme in much of the theoretical network literature that has emerged to study fixed-income trading, reflecting a significant extension of the original Duffie, Gârleanu, and Pedersen (2005) model in which dealers are homogenous and the interdealer

[29]Neklyudov (2019) offers a baseline search and matching model with heterogeneous search technology that leads to a centrality discount (lower spreads for central dealers than for peripheral dealers).

market is frictionless.[30] This article provides the foundation for the extensive theoretical literature on interdealer trading networks and intermediation chains that followed. Hugonnier, Lester, and Weill (2015) develop solution techniques to analyze a framework with general heterogeneity and examine model implications with regard to average time to trade, the distribution of the length of intermediation chains, the volume of trade in dealer–customer and interdealer trades, and the relation between intermediation chain length and the bid–ask spread, and to calibrate their model to market characteristics. In their framework, an agent with a median preference for holding bonds emerges in a central position and endogenously intermediates the order flow.

Given the widespread empirical importance of a core–periphery interdealer structure for a broad set of markets, a fundamental feature of network formation demonstrated by Wang (2018) is that a core–periphery structure arises as an endogenous response even when all agents are ex ante identical. An important facet of Wang's framework is that it provides a game theoretic foundation for the core–periphery structure in which agents who form the core do not have special ex ante advantages. Wang analyzes the equilibrium number of "core agents" (e.g., dealers) as reflecting a trade-off between the benefits of concentration, including lower inventory risk due to the ability to quickly offset trades, and enhanced price competition that may arise from the presence of a larger number of dealers.

Dealers can unwind unwanted inventory by trading with their own clients, or via the dealer network. Schultz (2017) shows that interdealer trades are more important than trades with customers for managing inventory risk in corporate bonds. Li and Schürhoff (2019) find that central dealers in municipal bond markets are more likely than peripheral dealers to trade on a principal basis and more likely to unwind the position with a customer than with another dealer. They also report that central dealers are associated with shorter intermediation chains and more informative trades, and Hollifield et al. (2017) report corresponding evidence for structured bonds. On balance, the results suggest that dealers with wider trading networks are better able to manage inventory risk and to extract information from customer order flow.

The empirical regularity that bid–ask spreads tend to be larger for small trades may also be a manifestation of the importance of dealer networks. In particular, Hugonnier, Lester, and Weill (2015) present a competitive model with a search friction, whereas in Bernhardt, Dvocracek, Hughson, and Werner's (2005) model, brokers who have more valuable relationships with dealers use more frequent and larger orders. Babus and Kondor (2018) argue that dealers with few trading partners (peripheral dealers) must execute smaller traders and face greater adverse selection and wider spreads (while aggregating less information) than dealers with more trading partners (central dealers). Complementing this asymmetric information analysis, Colliard, Foucault, and Hoffman (2018) analyze the effect of inventory on OTC dealer networks. Core dealers share the inventory costs in an efficient manner, providing liquidity to peripheral dealers who have

[30]Duffie, Gârleanu, and Pedersen (2007) extend the model to focus on how search affects asset pricing in the presence of risk aversion and risk limits.

heterogeneous access to them. This work analyzes the connection between inventory management and the structure of the interdealer trading network.

There is evidence indicating that bid–ask spreads paid by customers vary depending on a dealer's position in the network. Schultz (2001) shows that small bond dealers charge customers more than large dealers. Di Maggio, Kermani, and Song (2017) and Li and Schürhoff (2019) report evidence of a "centrality premium," by which central dealers charge customers significantly higher spreads than peripheral dealers for corporate and municipal bonds, respectively.[31] In contrast, Hollifield et al. (2017) report a negative relation between a dealer's centrality and bid–ask spreads in structured product markets. The theoretical model in Hollifield et al. suggests that the contrasting results across markets can be explained by differences in customer sophistication. Customers in structured bonds tend to be sophisticated institutional investors with more information and better alternatives as compared to retail investors, who are more important in corporate and municipal bonds. Issa and Jarnecic (2019) report that relationship strength is associated with higher client trade execution costs, except during periods of heightened information asymmetry when customer order flow is more valuable. In the interdealer market, Di Maggio et al. find that trading costs are significantly lower among dealers with strong trading relationships.

Trading relationships are relevant to trading costs paid not only across retail and institutional investors, but also for large versus small institutions (see Schultz (2001), Bessembinder et al. (2006), O'Hara et al. (2018), Hendershott, Li, Livdan, and Schürhoff (2017)). Schultz (2001) studies NAIC insurance company transactions in corporate bonds from 1995 to 1997, reporting that large institutions (based on the size of bond holdings) obtain lower trading costs than small institutions. Focusing on 2001–2011, O'Hara et al. (2018) report that trading cost differences across large and small insurance companies are i) larger for small-size trades (but not different for block trades), ii) larger when a dealer maintains a dominant market presence in the bond, and iii) smaller after introduction of TRACE reporting. Their evidence supports the reasoning that dealers possess sufficient market power to price discriminate among clients.

Hendershott et al. (2017) find that insurance companies typically form few, long-lasting relationships with dealers and that less active insurance companies benefit from a concentrated trading relationship with dealers.[32] Their model implies that customers trade off the benefits of existing relationships, including those that accrue outside of trading per se, against potential speed and execution improvements that could be obtained from searching across dealers. Empirically, they report a nonmonotonic relation between trading costs and network size in the corporate bond market.

[31] Using a broader sample and additional control variables, Goldstein and Hotchkiss (2020) obtain different results from Di Maggio et al. (2017) in applying network measures to corporate bonds.

[32] According to the 2017 Greenwich Associates North American Fixed Income survey, the typical institutional investor executes approximately 55% (85%) of their trading volume in investment-grade corporate bonds with their top 5 (10) dealers. According to the 2018 Citi report "Developments in Credit Market Liquidity," for 1 active (unnamed) corporate bond dealer, the top 25 (101) institutional clients account for 50% of total U.S. investment-grade volume.

B. Dealer Networks and Activity around New Bond Issuance

The impact of trading relationships is pronounced during the new bond issuance process. Investment banks negotiate terms with issuers, and their trading arms serve as dealers in the secondary market. Underwriting banks are compensated by purchasing the bond from the issuer at the offering price and placing it with customers at a higher reoffering price. Unlike Treasuries, where the primary allocation is determined by an auction that is open to the public, the allocation of corporate and municipal bonds to customers is at the discretion of the underwriting syndicate, similar to the standard practice for equity market initial public offerings (IPOs).[33] Customers with established underwriter relationships that help the syndicate by participating in a “cold” issue are likely to obtain better allocations in subsequent offerings. Allocations are valuable because of underpricing.[34] In addition, some institutions “flip” the bond on the first trading day by selling it to smaller dealers or institutions who did not obtain allocations in the primary offering.

Unlike equity offerings where the entire issue is sold at the reoffering price, Green et al. (2007a) find that a substantial portion of municipal bonds are sold to customers at a premium to the stated reoffering price. In particular, large purchases take place at or near the reoffering price, whereas small purchases involve substantial markups over the reoffering price. Schultz (2012) finds that the dispersion in purchase prices declines sharply with the introduction of trade reporting for municipal bonds in Jan. 2005. Markups over the reoffering price also tend to increase with the length of the sequence of interdealer trades that precede the eventual purchase by a bond investor.[35]

Corporate bonds trading activity tends to be greatest in recently issued bonds. According to Mizrach (2016), the share of overall market volume attributable to newly issued corporate bonds declines significantly 3 months after issuance, and the decline in trading activity in the quarter after bond issuance is substantially greater in 2015 than in 2007. The decline likely reflects both that long-horizon investors, such as insurance companies and pension funds, which implement buy-and-hold strategies, have acquired the bonds and that institutional investors are receiving higher allocations in recent years. The relation between new issuance and trading activity is particularly striking for Treasury bonds. Barclay, Hendershott, and Kotz (2006) report that upon the issuance of a new Treasury security, trading volume in the previously issued security of the same maturity drops by more than 90%.

[33]In the equity IPO context, Spatt and Srivastava (1991) demonstrate the potential optimality of a fixed-price mechanism with pre-play communication and participation restrictions for allocating a new issue.

[34]The magnitude of underpricing in corporate bonds averages approximately 50 bps and is more pronounced for riskier bonds (Datta, Iskandar-Datta, and Patel (1997), Cai, Helwege, and Warga (2007)) and mega bonds (Helwege and Wang (2017)). In Treasury bonds, underpricing is approximately 1 bp when the auction price is compared with the benchmark price on the auction day (Goldreich (2007)) and approximately 9 bps when compared with the benchmark price 5 days before the auction (Lou, Yan, and Zhang (2013)).

[35]Hollifield et al. (2017) note in the context of securitization trading that secondary market bid–ask spreads increase with chain length.

VII. Regulation of Fixed-Income Trading

Regulation plays a central role in the organization of fixed-income markets because of the classic liquidity externality associated with trading, issues of standardization and coordination in the design of markets, the potential importance of adverse selection, and the degree of delegated decision making to broker-dealers and investment funds. The 2008 financial crisis highlighted the importance of liquidity and systemic risk and led to a larger role for government and central banks in the fixed-income markets and their design.

A. Transparency

The regulation of fixed-income markets is influenced to a degree by the underlying market structure. A prominent example concerns market transparency, that is, the extent to which relevant market information is readily observable to all participants. For example, although a limit order market structure involves the continuous compilation of information regarding unexecuted orders at various prices, it naturally accommodates pre-trade transparency, but this is not an intrinsic feature of an OTC market. Similarly, because a limit order market necessarily gathers a record of all transactions that occur on the market, dissemination does not involve further information aggregation. In contrast, transaction price data in an OTC market are dispersed; therefore, dissemination requires additional information aggregation. Indeed, most fixed-income markets have moved toward post-trade transparency only since 2002, as a result of regulation.

The timing of the adoption of post-trade transparency varies across markets (see Table 3). U.S. regulators first moved to require post-trade transparency in markets they viewed as relatively more liquid, and they initially allowed dealers a delay between the time of a trade and its public report. This was done to avoid potential adverse liquidity consequences that could arise if a dealer were not able to hedge or sell a portion of his position before disclosure of the trade.

Despite the overall movement in recent years toward greater transparency in fixed-income markets, the SEC's FIMSAC recently proposed that the dissemination of prices for very large transactions (at least $10 million for investment grade and $5 million for high-yield bonds) be delayed for 48 hours.[36] Back, Liu, and Teguia (2019) provide a model showing that the disclosure of transaction prices conveys information possessed by the dealer about the asset quality and reduces the dealer's rents when she disposes of the inventory in a second transaction.

Much of the empirical literature on fixed-income trading has emerged in the aftermath of transaction prices becoming available through TRACE, which reflects mandatory reporting of OTC secondary market transactions in eligible fixed-income securities by all FINRA members. These prices were collected by FINRA even before they began to be disseminated to the public. For example, FINRA began to collect transaction prices for securitized products in May 2011

[36]FIMSAC had diverse views regarding the desirability of a price reporting delay, with academic members generally opposed and many industry members in favor, as evidenced in the transcript available at https://www.sec.gov/spotlight/fixed-income-advisory-committee/fimsa-040918transcript.txt. Some committee members wrote a dissenting letter, available at https://www.sec.gov/comments/265-30/265-30.htm.

with an eye toward public post-trade reporting, which was implemented for various securitized products at later dates, as summarized in Table 2. As a consequence, some authors were able to study transactions prices from still-opaque markets, reflecting FINRA's interest in understanding the characteristics of these markets before introducing transparent trading and pricing (Atanasov and Merrick (2012), Bessembinder et al. (2013), Friewald, Jankowitsch, and Subrahmanyam (2014), and Hollifield et al. (2017)).

The first 3 studies of transparency in the corporate bond market use different, but complementary, methods. The introduction of transparency in corporate bonds in July 2002 required price dissemination only for a set of liquid bonds, rather than a randomized control design. Goldstein et al. (2007) study the third set of bonds (all BBB rated) phased into transparency in Apr. 2003. These bonds were selected as a stratified random sample, along with a control sample of nondisseminated bonds. Edwards et al. (2007) compare execution costs for transactions disseminated to the public to those for trades not publicly disseminated between Jan. 2003 and Jan. 2005. Bessembinder et al. (2006) use a difference-in-difference design, studying changes in trade execution costs for insurance company bond trades in the NAIC database after July 2002 for bonds where transaction reporting was initially mandated as compared to bonds where it was not. Despite the differing samples and research designs, all 3 studies conclude that public transaction reporting through TRACE is associated with significant reductions in customer trade execution costs. The results in Bessembinder et al. (2006) also indicate the possibility of a "liquidity externality" by which trade reporting for some bonds led to reduced execution costs, even for bonds without transaction reporting (which would suggest that the bonds were competing as trading substitutes). The introduction of post-trade transparency has also been shown to be associated with reduced trading costs in CDS markets (Loon and Zhong (2016)), the TBA MBS market (Schultz and Song (2019)), and the Rule 144A corporate bond market (Jacobsen and Venkataraman (2018)).

In Europe, fixed-income securities traded without either pre- or post-trade transparency until the implementation of the Markets in Financial Instruments Directive (MiFID II) in Jan. 2018. MiFID II requires broker-dealers and trading venues (e.g., exchanges or electronic platforms) to report transactions in fixed-income securities, including sovereign bonds and corporate bonds, to a national regulator. The timing of public disclosure of transactions depends on security characteristics, transaction size, and the venue where the transaction is conducted.[37] Although the framework is complex, the guiding principles are that securities that are categorized by regulators as liquid and transactions that are deemed by regulators as nonblock (based on security and asset class specific size thresholds) are subject to real-time dissemination of completed transactions. MiFID II also includes a pre-trade transparency requirement to report individual bids and offers for small prospective transactions in a limited number (i.e., 200 bonds) of sovereign securities. As these data become available to researchers, it will be of interest to study whether the broad patterns observed in U.S. markets

[37] See the transcript of the SEC panel titled "Pre-Trade Transparency under MiFID II," available at https://www.sec.gov/spotlight/fixed-income-advisory-committee/fimsac-071618transcript.txt.

are also observed in European markets, and whether differences in country-level regulation within the European Union could explain variations in bond market quality across markets and securities.

B. Fairness in Pricing

Some of the key regulatory issues in fixed-income markets are oriented toward the fairness of pricing. In particular, regulators restrict price markups, thereby limiting dealer profits. It is atypical for financial regulators to regulate pricing directly, and such regulation may effectively limit the market power of dealers in thinly traded and relatively opaque search markets. Indeed, the enforcement of markup rules has been an important component of the regulatory agenda in fixed-income markets in recent years (see, e.g., http://www.seclaw.com/markups-markdowns/). By misstating the origins and history of a position, a dealer can misrepresent the pricing allowed under regulation and the willingness of a counterparty to accept a given price.[38] In the aftermath of an SEC enforcement action in 2015, both FINRA for corporate bonds and MSRB for municipal bonds passed rules effective May 14, 2018 requiring markup disclosure on confirmation slips for riskless principal trades.[39] The markup disclosure rule points to some interesting open questions. At a high level, the rule presents an opportunity to evaluate the importance of "consumer" disclosure requirements. For example, after the rule goes into effect, what happens to the implicit spread on riskless principal trades and the mix between principal and agency trades? How does this vary among instruments and dealers?

Traditional approaches to the regulation of equity markets have been adapted in the fixed-income markets to a limited degree. FINRA adopted a best execution rule for trading corporate bonds, and MSRB adopted such a rule for municipal bonds. However, there is no analogy to the equity-market order-handling rules (which require respecting the potential priority of orders that originate with investors rather than dealers) or to the order protection rule under Regulation NMS, which bans "trade-throughs" (i.e., the execution of a trade at a price worse than the best available quote).

The lack of systems for creating consolidated quotations in bond markets implies that many participants, particularly retail investors and smaller institutional traders, do not see the best available prices as they do in equities, and therefore they have difficulty identifying trade-throughs and in measuring execution quality. Harris (2015) documents a high proportion of trade-throughs in the corporate bond market when he compares trade prices to a nonpublic database of indicative quotations. A related problem is the lack of uniform practices regarding the quotation data produced by dealers and electronic venues. Larger institutions that have

[38] Enforcement actions by FINRA and the SEC arise due to violations of the markup rules. As a recent example, a dealer allegedly attempted to misstate the history of a bond acquisition and was prosecuted by the Department of Justice as a criminal matter (see Larson, E.; B. Van Voris; and C. Dolmetsch. "Tweaking Chat Trips Up Ex-Jefferies Bond Trader Jesse Litvak." Bloomberg. Available at https://www.bloomberg.com/news/articles/2017-01-27/tweaking-a-chat-trips-up-ex-jefferies-bond-trader-jesse-litvak (Jan. 27, 2017)).

[39] Of course, historically, agency trades have required commission disclosure. To the extent that implied commissions on riskless principal trades are large, the required markup disclosure could lead to resistance from retail clients and tighter implied commissions, especially on retail-sized transactions.

the resources to consolidate quotation data benefit from the information advantage. Nor do fixed-income markets have regulations analogous to SEC Rules 605 and 606, which require disclosure of order execution quality and broker order-routing procedures for equities. Regulatory initiatives that lead to a centralized quotation system with standardized price data could help investors better understand the quality of their trade executions.

C. Systemic Risk and Market Stability

The regulation of fixed-income markets in recent years has emphasized systemic risk and financial stability issues, as well as the impact of the changing environment on liquidity. Among other initiatives, regulators now require most standardized derivatives, including interest rate swaps, to be cleared through centralized clearinghouses. Benos, Payne, and Vasios (2019) study proprietary trading data and conclude that centralized clearing has reduced bid–ask spreads and enhanced liquidity, a result they attribute to enhanced competition between dealers.

At the heart of the changes in regulatory focus since the financial crisis is the Volcker Rule, an important part of the Dodd–Frank Act. The Volcker Rule restricts the trading activity of banks and major financial institutions to avoid subsidizing them in light of their regulatory advantages (e.g., deposit insurance, access to the Fed discount window, and implicit "too big to fail" guarantees) with the intent of mitigating incentives toward excessive risk taking in proprietary trading. The Volcker restrictions effectively bar proprietary trading desks and internal hedge funds for the affected institutions, resulting in their decisions to spin off these entities.

The effects of the Volcker Rule on market making are more complicated, and arguably more significant, for fixed-income markets. As Duffie (2012) observes, although the Volcker Rule allows market-making activities by banks, the distinction between a proprietary trade and a trade undertaken to facilitate customer activity is subtle. The empirical evidence discussed earlier supports the reasoning that the Volcker Rule has had the effect of reducing the willingness of dealers to commit capital to market making, even though the rule was not intended to affect market making.

In Aug. 2019, five US regulatory agencies approved a set of modifications to the Volcker Rule (dubbed by some observers as "Volcker Rule 2.0"), including a provision that "banking entities that trade within internal risk limits set under the conditions in this final rule are engaged in permissible market making."[40] Assessing the potential impact of this modification on the microstructure of fixed income trading also comprises an interesting avenue for future research.

Financial institutions may attribute part of the decline in committing their capital to fixed-income trading to the greater capital costs associated with higher bank capital (equity) requirements. In effect, the underlying structure of trading has changed in recent years; there is a move toward pre-arranged trading that does not rely on dealer inventory (Schultz (2017), Choi and Huh (2017)), as well as toward shorter intermediation chains. This can be seen as a natural response to the

[40]See https://www.fdic.gov/news/news/press/2019/pr19073.html and https://www.bloomberg.com/opinion/articles/2019-08-20/volcker-2-0-is-too-little-too-late-for-wall-street-s-traders.

changes in the regulatory environment and greater reluctance of dealers to commit capital. However, focusing only on capital supplied by bank-affiliated dealers potentially overstates the impact on the markets, because it does not capture endogenous responses such as the increased involvement of nonbank dealers, the growth in electronic intermediation services, or the effective provision of liquidity by customers through prearranged trades.

Harris (2015) observes that most bond brokers do not display limit orders from their customers in electronic bond trading systems, an important liquidity source in equity markets. Recent years have witnessed growth in "all-to-all" trading platforms that allow select buy-side institutions to participate in liquidity provision (e.g., Market Axess's Open Trading platform). Nonetheless, access remains limited, and the bond dealer remains involved in virtually all transactions between buyers and sellers. Regulatory initiatives that focus on increasing customer access can reduce the reliance on dealer capital and significantly expand the pool of liquidity suppliers.

Market making in Treasuries is presumably less affected by the Volcker Rule, as Treasury securities are less risky and more liquid as compared to speculative securities targeted by the Volcker Rule. It would be of interest to assess the extent to which dealer capital commitment to Treasury market making has changed in recent years, and to contrast the results to those for corporate bonds and analyze the impact on spreads.

Data on transactions in U.S. Treasury securities intermediated by SEC-registered broker-dealers is currently being collected by regulators through TRACE under an initiative of the Treasury and SEC, but the data have not yet been made available to academics for analysis (though they are available to at least some researchers within regulatory institutions). The trade-offs facing Treasury officials, who are responsible for both financial stability and government funding costs, are of particular interest. It could be argued that Treasuries (and perhaps some other sovereigns) should be exempt from the Volcker Rule, as they are subject to less credit risk, and the Volcker Rule is intended to limit risk taking and the costs of too-big-to-fail guarantees. Of course, government bonds are subject to interest rate risk, and sovereign credit is not necessarily free of default risk. Under crisis conditions in particular, the challenges to sovereign credit would be greatest and the implications of the Volcker Rule would be most germane.

Indeed, in the parallel context of bank capital adequacy, the use of "zero risk" weights for sovereign credit has been widely criticized in Europe and has potentially created vulnerability to sovereign credit issues. More broadly, regulatory policies and the use of unconventional monetary policy may have reduced the willingness to commit dealer capital to market making. In contrast to the Modigliani–Miller irrelevance propositions central to academic thinking, financial institutions appear to view equity capital as especially costly, so higher equity capital requirements (under Basel and U.S. regulation) also would be expected to result in less dealer capital being allocated to market making.

Among the environmental changes that may have affected the commitment of dealer capital to market making are the enhancement of transparency for structured products, as dealers have argued that greater transparency reduces the profitability of market making, as well as other changes in market conditions. Both low interest rates and increases in interest rate volatility potentially affect the willingness of dealers to commit capital to market making.[41]

The nature of market making has adjusted in response to the changing environment, as hedge funds and the buy side partially fill the void created by reduced bank involvement. Dick-Nielsen and Rossi (2019) study bond index exclusion events and conclude that liquidity is reduced around these events, requiring greater customer patience, and Bessembinder et al. (2018) document increased market participation by nonbank market makers. Researchers (e.g., Ellul, Jotikasthira, and Lundblad (2011), Choi and Shin (2018)) document the existence of "fire sales" in corporate bond markets, where the need to sell specific bonds results in temporary downward price pressure. In extreme circumstances, the reduced availability of capital for market making could result in fire sales of increased magnitude. Although the goal of the Volcker Rule is to increase financial stability, the potential for increased fire sales implies that stability may be reduced instead, which could increase the desirability of maintaining standby capital (see Menkveld (2016)).

Although regulatory and monetary policy each arguably contributes to a perception of a recent decline in fixed-income market liquidity, it would be a mistake to conclude that liquidity before the financial crisis was necessarily optimal and therefore provides the right benchmark. In particular, the period before the financial crisis may have been characterized by unrecognized costs that were not internalized by institutions deemed too big to fail and that emerged only during the financial crisis.

D. Bond Exchange-Traded Funds and Mutual Funds

Investors can obtain exposure to fixed-income markets by purchasing individual instruments or ownership interests through mutual funds or exchange-traded funds (ETFs). Funds provide an important mechanism for obtaining liquidity, especially in light of the limited liquidity associated with the dispersed trading of individual instruments. Theory (e.g., Subrahmanyam (1991), Gorton and Pennacchi (1993)) predicts that portfolio liquidity should be superior to that of individual instruments, because of reduced adverse selection.

At the same time, there are structural issues associated with fixed-income portfolio trading. The open-end mutual fund model is priced on a daily basis, based on closing valuations of the underlying assets. A question that arises is whether the apparent liquidity of the composite portfolio could be illusionary. Many open-end funds allow investors to transact at the fund closing price, which is in turn based on the closing prices of the underlying holdings. This offers an illusion of costless liquidity (see Spatt (2014)), though it is not actually costless for a mutual fund to offer such liquidity. In an attempt to mitigate the possibility of "runs" by mutual fund investors, recent regulatory changes allow the use of "swing pricing," by which a mutual fund can attempt to internalize the consequences of substantial orders at the close.

[41] It would be interesting to examine how changes to the monetary policy interest rate environment (e.g., changing interest rate levels, interest rate volatility, and Fed ownership of longer term debt under "Quantitative Easing" programs) influence market making, including the number of dealers and dealer capital measures.

The liquidity mismatch also arises between individual bonds and ETFs, though they are all traded instruments. An ETF is traded directly on stock exchanges throughout the trading day, and its price is anchored to those of its components through a redemption and creation mechanism for the underlying fund in which only a limited set of "authorized participants" can engage in the arbitrage mechanism. The lower liquidity of underlying credit instruments relative to that of the ETF potentially increases the fragility of liquid ETFs and reduces the arbitrage capacity of ETF markets. Indeed, when the conflict in the roles of authorized participants as bond dealers and ETF arbitrageurs is large, mispricing can arise (see Pan and Zeng (2017), Goldstein, Jiang, and Ng (2017)).[42]

Because many individual bonds are highly illiquid, bond index funds often rely on sampling methods rather than purchasing all of the bonds that compose the index to be replicated. Of course, the discrepancy between trading individual bonds and a fund offering costless liquidity through closing prices is greater when the underlying component assets held by the mutual fund are themselves highly illiquid. On Oct. 16, 2016, the SEC adopted reporting requirements for mutual fund liquidity to quantify for regulators and the public the extent to which assets could be sold over a specified interval. However, these requirements have been the subject of active debate, and the final rule adopted on Sept. 10, 2018 only requires funds to disclose information about the operation and effectiveness of their liquidity risk management program (https://www.sec.gov/rules/final/2018/ic-33142.pdf). Managers of index funds are often evaluated based on the performance of their fund relative to the specified index. However, the weighting on individual bonds in the index changes each month, as new bonds are issued, existing bonds approach maturity, and so on. Ottonello (2019) documents predictable patterns in bond returns related to the combination of mutual funds rebalance trading and the illiquidity of the underlying bonds.

Because mutual funds normally hold some cash reserves, they potentially supply liquidity at times. Wang, Zhang, and Zhang (2018) document that mutual funds constitute an important source of liquidity supply when other market participants are forced to sell bonds. Anand, Jotikasthira, and Venkataraman (2018) show that some bond mutual funds exhibit a persistent trading style that supplies liquidity by absorbing the inventory positions of dealers. To the extent that liquidity management rules in the event of a shock preclude a mutual fund from being a net buyer, such rules may lead to more dramatic fire sales.

E. Short-Term Funds

The financial crisis also highlights the importance of the market structure for short-term financial instruments. Money market mutual funds in particular played an important role during the financial crisis. These issues arose in the aftermath of the collapse of Reserve Fund, which did not have policies and procedures in

[42]Many ETFs require the authorized participants to exchange the ETF for a basket of securities. An in-kind redemption mechanism allows the ETF to avoid selling securities to raise cash to meet redemptions. Under stressful market conditions, it is important to understand whether in-kind redemptions work smoothly, whether price discovery occurs at the ETF or the underlying bonds, and the relevance of publishing intraday net asset values (NAVs) that are possibly incorrect when the underlying bond market is illiquid.

place to adjust its valuation from the $1 per share level considered standard for money market funds, even in the face of adverse events. The conversion of shares to cash was suspended, setting off a run on money market mutual funds. This run was amplified by the custom of pricing funds at $1 rather than marking the NAV to market.

Schmidt, Timmerman, and Wermers (2016) study the aftermath of the Lehman Brothers collapse, showing that institutional products are more susceptible to runs. A series of reforms emerged after the Lehman Brothers collapse, intended to ensure that funds have appropriate policies and procedures for altering their valuations, to limit the riskiness of the assets in the fund, and to require floating NAVs for institutional funds that invest in nongovernmental securities. These reforms led to a substantial reduction in the holdings and size of money market mutual funds, especially institutional "prime portfolios," effectively transforming the U.S. system of short-term financing. Much of the institutional holdings shifted to governmental money market funds from prime (nongovernmental) funds, suggesting considerable demand for quasi-fixed pricing.

F. Fed Policy and Fixed-Income Markets

Another structural change in the aftermath of the financial crisis is the extent of central bank participation in various fixed-income markets. In particular, the Fed dramatically expanded its balance sheet and acquired a substantial portion of outstanding MBS, reflecting efforts to circumvent limitations on monetary policy attributable to the nominal "zero interest rate bound."[43] In addition to providing direct support to the housing market, this led to a substantial increase in the maturity and duration profile of Fed holdings.[44] Of course, the underlying issues are not specific to the United States, as the consequences of the zero interest rate bound are relevant around the globe. For example, a recent *Wall Street Journal* article reports that the European Central Bank (ECB) became one of the largest buyers of corporate bonds a few years ago, which has had substantial effects on narrowing interest rate spreads between Treasuries and corporate bonds, and across the credit spectrum.[45]

The effects of central bank transactions on the microstructure of fixed-income markets constitute a promising research area. Among the contributions, Schlepper, Hofer, Riordan, and Schrimpf (2019) study ECB activity, reporting that greater purchases are associated with lower transactions costs but reduced book depth. Pasquariello, Roush, and Vega (2019) develop a model implying that

[43] An alternative way (compared to holding long-term bonds) for a central bank to engage in expansionary policy near the zero interest bound is to support negative interest rates (e.g., by taxing deposits and/or currency).

[44] This was viewed as somewhat controversial because of the extent of active credit allocation undertaken by the Fed and questions about whether the macroeconomy/monetary policy required such activities. The first round of the Fed's balance sheet expansion, QE, was widely supported as part of the response to the core of the financial crisis, but subsequent rounds, QE2 and QE3, were more controversial and perhaps less effective, as there was less of a surprise, diminishing returns and increasing concerns about the difficulty of unwinding these exposures.

[45] Bird, M. "Investors Prepare for the End of ECB's Corporate-Bond Buying." https://www.wsj.com/articles/investors-prepare-for-the-end-of-ecbs-corporate-bond-buying-1520591407. *Wall Street Journal* (Mar. 9, 2018).

greater central bank activity should improve liquidity despite heightened information asymmetry, and they report supportive evidence for U.S. markets.

VIII. Some Open Questions

Although there have been considerable advances in understanding the microstructure of fixed-income markets over the years, there remains a range of important and interesting unresolved questions. Among the most fundamental questions is why trading costs tend to be higher in dealer-oriented fixed-income markets as compared to equity markets. Are fixed-income markets structured optimally? The large number of individual issues, infrequent trading, and the relative dearth of retail participation are clearly relevant but may reflect endogenous outcomes. That is, to what extent do infrequent trading and a lack of retail participation result from higher execution costs? Are higher execution costs an inherent feature of dealer-oriented OTC markets, or are such markets the optimal mechanism for liquidity provision in light of the costs associated with infrequent trading and search? Would the market function more effectively if it were more consolidated? If so, how can the consolidation of a search-oriented dealer market be facilitated?

Currently, most customers have limited access to fixed-income markets, as they may not be able to observe in real time even the indicative quotes that are available from dealers, and their orders are not displayed as quotations to other market participants. Would regulations requiring the public display of customer trading interest (along the lines of the 1997 NASDAQ equity market reforms studied by Barclay, Christie, Harris, Kandel, and Schultz (1999)) as advocated by Harris (2015) improve the functioning of fixed-income markets? More broadly, would regulations requiring all quotations and indications of interest, whether originating with customers or dealers, to be consolidated and publicly displayed enhance the functioning of fixed-income markets? What would be the effect of requiring that electronically disseminated quotations be firm and subject to automated execution?

Many of these questions relate to whether the market or portions of it should be organized more like an exchange rather than an OTC market. An interesting perspective that bears on this indirectly by explaining the prevalence of intermediation chains is Glode and Opp (2016), who suggest that a chain of moderately informed intermediaries can mitigate market power compared to a market structure organized around a dominant broker (or exchange) and that a multiround intermediation chain can reduce adverse selection. Long intermediation chains can lead to limited adverse selection at each stage of trading to avoid the breakdown of trading, providing a fundamental explanation for intermediation chains and the emergence of trading networks. Glode and Opp (2020) argue that the OTC markets where most fixed-income trading occurs encourage the acquisition of expertise, which is useful when it improves the efficiency of allocations but problematic when it results in adverse selection. This provides a potential explanation for the coexistence of exchange and OTC trading and the choice of trading protocol for different types of instruments. Lee and Wang (2018) present a model where investors can choose between OTC and exchange trading, showing that dealers' ability to price discriminate can benefit customers in some cases.

Closely related is the need to better understand the differential relation between trading costs and trade sizes across fixed-income and equity markets. Do fixed-income markets inherently favor large and sophisticated customers who are better informed and better able to negotiate as compared to retail customers? Markup restrictions on bond pricing play an important role in the regulation of fixed-income markets but lack a direct counterpart in the equity markets at least since the abandonment of "price continuity" rules along with the specialist system on the New York Stock Exchange. The underlying question is in which markets and circumstances do direct restrictions on pricing improve outcomes?

Differences in regulatory treatment and instrument characteristics across equity and bond markets can potentially be exploited to enhance our understanding of these issues. For example, to what degree do best execution requirements in the bond market have bite as compared to the equity market, and how might these requirements be better tailored to the specific circumstances of the fixed-income markets? These issues are tied to whether there should be a centralized market: Is it more advantageous to promote competition among dealers or intermediaries to reduce trading fees or to facilitate competition across orders to achieve the best price execution?

As noted, fixed-income instruments tend to trade infrequently, in part because of the large number of unique instruments issued. To what extent is there scope to increase trading frequencies and decrease trading costs by consolidating instruments?[46] Helwege and Wang (2017) study very large bond offerings as compared to multiple simultaneous smaller offerings by the same issuer and conclude that although liquidity is improved for mega issues, yields are not lower, a result they attribute to price pressure associated with issue size. An alternative is to issue identical securities at multiple dates. In "tack-on" offerings, the terms of new issues are selected to match those of an existing issue. However, tack-on offerings are uncommon.[47] Are tack-on issues fully fungible with existing issues? More broadly, are there inefficient impediments to such issues? In mortgage markets, TBA instruments, which are packages of yet-to-be issued SP instruments, trade frequently with relatively low customer costs. Is there scope for the trading of packages of corporate bonds based on a set of prescribed characteristics, along the lines of "blind auction" transactions in equity markets (see Kavajecz and Keim (2005))?

Another prominent and unresolved issue concerns the role of post-trade transparency in fixed-income markets. Though several studies have considered changes in post-trade transparency, the optimal degree of transparency has not been established, as illustrated by the ongoing debate about whether the dissemination of information regarding large trades should be delayed. Much of the evidence regarding post-trade transparency focuses on execution costs for completed trades, which may reflect a degree of order splitting, and do not capture the potential cost and difficulty in executing large orders. Dealers, and in some cases

[46] Garriott, Lefebvre, Nolin, Rivadeneyra, and Walton (2018) provide specific proposals for consolidation of sovereign debt issues.

[47] Goh and Yang (2018) report only 77 tack-on offerings from 2006 to 2016.

large buy-side investors, are often critical of greater transparency. It would be beneficial to further investigate the economic issues underlying the dealers' perspective. Is it simply that market making is less profitable for dealers in a transparent setting, or is liquidity for large orders reduced such that large buy-side customers are disadvantaged by transparency? Furthermore, in light of the large number of instruments and cross-sectional variation in both clientele and trading frequencies, the transparency regime that is optimal in one fixed-income market may not be optimal in another.

As noted, the extent of electronic quotation and trading in fixed-income markets has been modest, particularly as compared to equity markets. However, the role of electronically facilitated trading in fixed-income markets is growing, and electronic interdealer trading of Treasury instruments is routine. Still, future growth in the electronic trading of fixed income instruments is far from guaranteed.[48] U.S. Treasury markets were, on Oct. 15, 2014, subject to a "flash crash" where the yield on the 10-year Treasury note dropped by 16 bps and then recovered, within a 12-minute period.[49] This incident raises the question of whether algorithmic trading is associated with an inherent potential for instability. It will be of interest to assess the effects of electronically facilitated trading on fixed-income microstructure outcomes as its role increases. More broadly, it is periodically asserted that financial crises tend to originate in credit markets. Studies of fixed-income microstructure focusing on how regulations affect liquidity provision, execution costs, and trades' price impacts have the potential to inform policy makers regarding the effects of policy initiatives on the fragility of credit markets.

An interesting puzzle related to the municipal bond market is the widespread use of municipal bond insurance before the financial crisis. Why would the capital market not simply bear the default risk just as it bears (and shares) so many types of capital market risks? Default risks are presumably positively correlated across bonds and, as such, have a substantial systematic component. To the extent the insurance is credible, it should result in instruments that are relatively more substitutable. One hypothetical advantage of such increased fungibility is to support the use of forward or futures contracts in which different insured instruments can be delivered, thereby potentially resulting in improved liquidity, similar to TBA MBS or the trading of generic MBS instruments as opposed to those "on special" (because of their prepayment or perhaps default characteristics, as discussed by Spatt (2004)). Of course, the fungibility of municipal bonds might still be limited by differences in tax treatment associated with the within-state tax exemption.

[48]Notable failures of electronic bond platforms have been observed, including BondBook (which was backed by several major Wall Street firms (see Parry, J. "BondBook, an Online Bond-Trading Site, Closes Down Despite High-Profile Backers." *Wall Street Journal.* Available at https://www.wsj.com/articles/SB1004385008243215960 (Oct. 30, 2001)) and Aladdin, which was backed by BlackRock (see Grind, K., and T. Demos. "BlackRock Shelves Platform for Bonds." *Wall Street Journal.* Available at https://www.wsj.com/articles/SB10001424127887323551004578441053526969438 (Apr. 23, 2013)).

[49]The official U.S. government report on the Treasury market event of Oct. 15, 2014 is available at https://www.treasury.gov/press-center/press-releases/Documents/Joint_Staff_Report_Treasury_10-15-2015.pdf.

The shorting and lending of fixed-income securities has received relatively little attention relative to equity markets.[50] This also seems to be an important area of research in light of the limited liquidity in most bond markets and the lack of transparency about the shorting process (in the equity as well as fixed-income markets).

As noted, in recent years the magnitude of bond issuances has far outstripped that of equity issues. Equity issuances, including both IPOs and seasoned equity offerings (SEOs) has been studied extensively, in terms of both issue pricing and post-issue liquidity. In contrast, the issuance process and microstructure of fixed-income issues has been little studied. Furthermore, the diversity of fixed-income instruments implies that regularities established for one segment of the fixed-income markets (e.g., Treasuries) may not carry over to other segments (e.g., corporate or municipal bonds).

A substantial portion of the empirical research related to fixed-income microstructure focuses on data generated during or after the financial crisis, which were periods of unconventional monetary policy. As a consequence, it is desirable to develop a better understanding of the interrelations between monetary policy, post-crisis regulations, and microstructure outcomes. For example, how does the impact of the zero interest rate bound affect monetary policy, interest rates, and the liquidity of instruments that may be involved in nontraditional policy? How do changes in the Fed's ownership of various instruments under quantitative easing and successor policies influence spreads, the number of dealers, and dealer capital? What can we learn about optimal market structure from cross-country comparisons, particularly in light of the variation in monetary policies across countries?

Monetary policy affects corporate issuance decisions, due in part to its effects on interest rates. The near-zero interest rates over the last decade are associated with a record amount of corporate bond issuance, with Triple B–rated corporate bonds now representing almost 50% of all outstanding investment-grade debt. Does the combination of increased market size, decreased creditworthiness, and dealers who may be less inclined to commit capital to market making imply that a future economic downturn could prompt larger fire sales and greater financial fragility?

References

Abudy, M., and A. Wohl. "Corporate Bond Trading on a Limit Order Book Exchange." *Review of Finance*, 22 (2018), 1413–1440.

Adrian, T.; M. Fleming; O. Shachar; and E. Vogt. "Market Liquidity after the Financial Crisis." *Annual Review of Financial Economics*, 9 (2017), 43–83.

Adrian, T.; M. Fleming; and E. Vogt. "An Index of Treasury Market Liquidity, 1991–2017." Staff Reports, Federal Reserve Bank of New York (2017).

Amihud, Y. "Illiquidity and Stock Returns: Cross-section and Time-Series Effects." *Journal of Financial Markets*, 5 (2002), 31–56.

Amihud, Y., and H. Mendelson. "Asset Pricing and the Bid–Ask Spread." *Journal of Financial Economics*, 17 (1986), 223–249.

Amihud, Y., and H. Mendelson. "Liquidity, Maturity, and the Yields on U.S. Treasury Securities." *Journal of Finance*, 46 (1991), 1411–1425.

[50] At the same time, there is interesting research about the Treasury repo specials market, as illustrated by Duffie (1996), Jordan and Jordan (1997), and Fleming and Garbade (2007).

Anand, A.; P. Irvine; A. Puckett; and K. Venkataraman. "Performance of Institutional Trading Desks: An Analysis of Persistence in Trading Costs." *Review of Financial Studies*, 25 (2012), 557–598.

Anand, A.; C. Jotikasthira; and K. Venkataraman. "Do Buy-Side Institutions Supply Liquidity in Bond Markets? Evidence from Mutual Funds." Working Paper, available at ssrn.com/abstract=3003189 (2018).

Anderson, M.; B. J. Henderson; and N. Pearson. "Bond Lending and Bond Returns." Working Paper, available at ssrn.com/abstract=3110771 (2018).

Anderson, M., and R. Stulz. "Is Post-Crisis Bond Liquidity Lower?" Working Paper, available at ssrn.com/abstract=2943020 (2017).

Asquith, P.; A. Au; T. Covert; and P. Pathak. "The Market for Borrowing Corporate Bonds." *Journal of Financial Economics*, 107 (2013), 155–182.

Atanasov, V., and J. J. Merrick Jr.. "Liquidity and Value in the Deep vs. Shallow Ends of Mortgage-Backed Securities Pools." Working Paper, College of William and Mary (2012).

Babus, A., and P. Kondor. "Trading and Information Diffusion in Over-the-Counter Markets." *Econometrica*, 86 (2018), 1727–1769.

Back, K., and K. Crotty. "The Informational Role of Stock and Bond Volume." *Review of Financial Studies*, 28 (2015), 1381–1427.

Back, K.; R. Liu; and A. Teguia. "Signaling in OTC Markets: Benefits and Costs of Transparency." *Journal of Financial and Quantitative Analysis* (2019). doi:10.1017/S0022109018001394.

Balduzzi, P.; E. J. Elton; and T. C. Green. "Economic News and Bond Prices: Evidence from the U.S. Treasury Market." *Journal of Financial and Quantitative Analysis*, 36 (2001), 523–543.

Bao, J.; M. O'Hara; and A. Zhou. "The Volcker Rule and Market-Making in Times of Stress." *Journal of Financial Economics*, 130 (2018), 95–113.

Bao, J.; J. Pan; and J. Wang. "The Illiquidity of Corporate Bonds." *Journal of Finance*, 66 (2011), 911–946.

Barclay, M. J.; W. Christie; J. Harris; E. Kandel; and P. Schultz. "Effects of Market Reform on the Trading Costs and Depths of Nasdaq Stocks." *Journal of Financial Economics*, 64 (1999), 1–34.

Barclay, M. J.; T. Hendershott; and K. Kotz. "Automation versus Intermediation: Evidence from Treasuries Going Off the Run." *Journal of Finance*, 61 (2006), 2395–2414.

Beber, A., and M. Pagano. "Short-Selling Bans around the World: Evidence from the 2007–2009 Financial Crisis." *Journal of Finance*, 68 (2013), 343–381.

Benos, E.; R. Payne; and M. Vasios. "Centralized Trading, Transparency, and Interest Rate Swap Market Liquidity: Evidence from the Implementation of the Dodd–Frank Act." *Journal of Financial and Quantitative Analysis* (2019). doi:10.1017/S0022109018001527.

Bernhardt, D.; V. Dvoracek; E. Hughson; and I. Werner. "Why Do Larger Order Receive Discounts on the London Stock Exchange?" *Review of Financial Studies*, 18 (2005), 1343–1368.

Bessembinder, H.; S. Jacobsen; W. Maxwell; and K. Venkataraman. "Capital Commitment and Illiquidity in Corporate Bonds." *Journal of Finance*, 73 (2018), 1615–1661.

Bessembinder, H.; K. Kahle; W. Maxwell; and D. Xu. "Measuring Abnormal Bond Performance." *Review of Financial Studies*, 22 (2009), 4219–4258.

Bessembinder, H.; W. Maxwell; and K. Venkataraman. "Market Transparency, Liquidity Externalities, and Institutional Trading Costs in Corporate Bonds." *Journal of Financial Economics*, 82 (2006), 251–288.

Bessembinder, H.; W. Maxwell; and K. Venkataraman. "Trading Activity and Transactions Costs in Structured Credit Products." *Financial Analysts Journal*, 69 (2013), 55–67.

Biais, B., and R. Green. "The Microstructure of the Bond Market in the 20th Century." *Review of Economic Dynamics*, 33 (2019), 250–271.

Bongaerts, D.; F. de Jong; and J. Driessen. "An Asset Pricing Approach to Liquidity Effects in Corporate Bond Markets." *Review of Financial Studies*, 30 (2017), 1229–1269.

Boni, L., and C. Leach. "Expandable Limit Order Markets." *Journal of Financial Markets*, 7 (2004), 145–185.

Brandt, M., and K. Kavajecz. "Price Discovery in the U.S. Treasury Markets: The Impact of Orderflow and Liquidity on the Yield Curve." *Journal of Finance*, 59 (2004), 2623–2654.

Cai, N.; J. Helwege; and A. Warga. "Underpricing in the Corporate Bond Market." *Review of Financial Studies*, 20 (2007), 2021–2046.

Chakravarty, S., and A. Sarkar. "Trading Costs in Three U.S Bond Markets." *Journal of Fixed Income*, 13 (2003), 39–48.

Chalmers, J.; Y. Liu; and Z. J. Wang. "The Difference a Day Makes: Timely Disclosure and Trading Efficiency in the Muni Market." Working Paper, available at ssrn.com/abstract=2786420 (2019).

Chen, L.; D. Lesmond; and J. Wei. "Corporate Yield Spreads and Bond Liquidity." *Journal of Finance*, 52 (2007), 119–149.

Chen, X.; J. Huang; Z. Sun; T. Yao; and T. Yu. "Liquidity Premium in the Eye of the Beholder: An Analysis of the Clientele Effect in the Corporate Bond Market." Working Paper, available at ssrn.com/abstract=2269894 (2018).

Choi, J., and Y. Huh. "Customer Liquidity Provision: Implications for Corporate Bond Transaction Costs." Working Paper, available at ssrn.com/abstract=2848344 (2017).

Choi, J., and S. Shin. "Liquidity-Sensitive Trading and Corporate Bond Fund Fire Sales." Working Paper, available at ssrn.com/abstract=2731844 (2018).

Chordia, T.; R. Roll; and A. Subrahmanyam. "Liquidity and Market Efficiency." *Journal of Financial Economics*, 87 (2008), 249–268.

Colliard, J.; T. Foucault; and P. Hoffmann. "Inventory Management, Dealers' Connections, and Prices in OTC Markets." Working Paper, HEC Paris School of Management (2018).

Corwin, S., and P. Schultz. "A Simple Way to Estimate Bid–Ask Spreads from Daily High and Low Prices." *Journal of Finance*, 67 (2012), 719–760.

Das, S.; M. Kalimipalli; and S. Nayak. "Did CDS Trading Improve the Market for Corporate Bonds?" *Journal of Financial Economics*, 111 (2014), 495–525.

Datta, S.; M. Iskandar-Datta; and A. Patel. "The Pricing of Initial Public Offers of Corporate Straight Debt." *Journal of Finance*, 52 (1997), 379–396.

Diamond, D., and R. Verrecchia. "Constraints on Short-Selling and Asset Price Adjustment to Private Information." *Journal of Financial Economics*, 18 (1987), 277–311.

Dick-Nielsen, J.; P. Feldhütter; and D. Lando. "Corporate Bond Liquidity Before and After the Onset of the Subprime Crisis." *Journal of Financial Economics*, 103 (2012), 471–492.

Dick-Nielsen, J., and M. Rossi. "The Cost of Immediacy for Corporate Bonds." *Review of Financial Studies*, 32 (2019), 1–41.

Di Maggio, M.; A. Kermani; and Z. Song. "The Value of Trading Relationships in Turbulent Times." *Journal of Financial Economics*, 124 (2017), 266–284.

Downing, C.; S. Underwood; and Y. Xing. "The Relative Efficiency of Stocks and Bonds: An Intraday Analysis." *Journal of Financial and Quantitative Analysis*, 44 (2009), 1081–1102.

Downing, C., and F. Zhang. "Trading Activity and Price Volatility in the Municipal Bond Market." *Journal of Finance*, 59 (2004), 899–931.

Duffie, D. "Special Repo Rates." *Journal of Finance*, 51 (1996), 493–526.

Duffie, D. "Market Making under the Proposed Volcker Rule." Working Paper, Stanford University (2012).

Duffie, D. "Post Crisis Bank Regulations and Financial Market Liquidity." Baffi Lecture, Banca d'Italia, Rome, Italy. Available at https://www.darrellduffie.com/uploads/policy/DuffieBaffiLecture2018.pdf (2018).

Duffie, D.; N. Gârleanu; and L. H. Pedersen. "Over-the-Counter Markets." *Econometrica*, 73 (2005), 1815–1847.

Duffie, D.; N. Gârleanu; and L. H. Pedersen. "Valuation in Over-the-Counter Markets." *Review of Financial Studies*, 20 (2007), 1865–1900.

Duffie, D., and H. Zhu. "Size Discovery." *Review of Financial Studies*, 30 (2017), 1095–1150.

Edwards, A.; L. Harris; and M. Piwowar. "Corporate Bond Market Transaction Costs and Transparency." *Journal of Finance*, 62 (2007), 1421–1451.

Ellul, A.; C. Jotikasthira; and C. T. Lundblad. "Regulatory Pressure and Fire Sales in the Corporate Bond Market." *Journal of Financial Economics*, 101 (2011), 596–620.

Feldhutter, P. "The Same Bond at Different Prices: Identifying Search Frictions and Selling Pressures." *Review of Financial Studies*, 25 (2012), 1155–1206.

Fleming, M. J., and K. B. Garbade. "Dealer Behavior in the Specials Market for US Treasury Securities." *Journal of Financial Intermediation*, 16 (2007), 204–228.

Fleming, M. J.; B. Mizrach; and G. Nguyen. "The Microstructure of a U.S. Treasury ECN: The BrokerTec Platform." *Journal of Financial Markets*, 40 (2018), 2–22.

Fleming, M. J., and G. Nguyen. "Price and Size Discovery in Financial Markets: Evidence from the U.S. Treasury Securities Market." *Review of Asset Pricing Studies*, forthcoming (2020).

Fleming, M. J., and E. M. Remolona. "Price Formation and Liquidity in the U.S. Treasury Market: The Response to Public Information." *Journal of Finance*, 54 (1999), 1901–1915.

Fleming, M. J.; E. Schaumburg; and R. Yang. "The Evolution of Workups in the U.S. Treasury Securities Market." *Liberty Street Economics*. Available at https://libertystreeteconomics.newyorkfed.org/2015/08/the-evolution-of-workups-in-the-us-treasury-securities-market.html (2015).

French, K., and R. Roll. "Stock Return Variances: The Arrival of Information and Reaction of Traders." *Journal of Financial Economics*, 17 (1986), 5–26.

Friewald, N.; R. Jankowitsch; and M. G. Subrahmanyam. "Illiquidity or Credit Deterioration: A Study of Liquidity in the U.S. Corporate Bond Market during Financial Crises." *Journal of Financial Economics*, 105 (2012), 18–36.

Friewald, N.; R. Jankowitsch; and M. G. Subrahmanyam. "Transparency and Liquidity in the Structured Bond Market." Working Paper, New York University (2014).
Friewald, N., and F. Nagler. "Over-the-Counter Market Frictions and Yield Spread Changes." *Journal of Finance*, forthcoming (2020).
Gao, P.; P. Schultz; and Z. Song. "Liquidity in a Market for Unique Assets: Specified Pool and To-Be-Announced Trading in the Mortgage-Backed Securities Market." *Journal of Finance*, 72 (2017), 1119–1170.
Garriott, C.; S. Lefebvre; G. Nolin; F. Rivadeneyra; and A. Walton. "Alternative Futures for Government of Canada Debt Management." Working Paper, Bank of Canada (2018).
Glode, V., and C. Opp. "Asymmetric Information and Intermediation Chains." *American Economic Review*, 106 (2016), 2699–2721.
Glode, V., and C. Opp. "Over-the-Counter vs. Limit-Order Markets: The Role of Traders' Expertise." *Review of Financial Studies*, forthcoming (2020).
Goh, J., and L. Yang. "Do Demand Curves for Bonds Slope Down?" Working Paper, Singapore Management University (2018).
Goldreich, D. "Underpricing in Discriminatory and Uniform-Price Treasury Auctions." *Journal of Financial and Quantitative Analysis*, 42 (2007), 443–466.
Goldstein, I.; H. Jiang; and D. Ng. "Investor Flows and Fragility in Corporate Bond Markets." *Journal of Financial Economics*, 126 (2017), 592–613.
Goldstein, M., and E. Hotchkiss. "Providing Liquidity in an Illiquid Market: Dealer Behavior in U.S. Corporate Bonds." *Journal of Financial Economics*, forthcoming (2020).
Goldstein, M.; E. Hotchkiss; and E. Sirri. "Transparency and Liquidity: A Controlled Experiment on Corporate Bonds." *Review of Financial Studies*, 20 (2007), 235–273.
Gorton, G., and G. Pennacchi. "Security Baskets and Index-Linked Securities." *Journal of Business*, 66 (1993), 1–27.
Green, R. C.; B. Hollifield; and N. Schürhoff. "Dealer Intermediation and Price Behavior in the Aftermarket for New Bond Issues." *Journal of Financial Economics*, 86 (2007a), 643–682.
Green, R. C.; B. Hollifield; and N. Schürhoff. "Financial Intermediation and the Costs of Trading in an Opaque Market." *Review of Financial Studies*, 20 (2007b), 275–314.
Green, R. C.; D. Li; and N. Schürhoff. "Price Discovery in Illiquid Markets: Do Financial Asset Prices Rise Faster Than They Fall?" *Journal of Finance*, 65 (2010), 1669–1702.
Green, T. C. "Economic News and the Impact of Trading on Bond Prices." *Journal of Finance*, 59 (2004), 1201–1233.
Harris, L. E. "Transaction Costs, Trade Throughs, and Riskless Principal Trading in Corporate Bond Markets." Working Paper, University of Southern California (2015).
Harris, L. E., and M. S. Piwowar. "Secondary Trading Costs in the Municipal Bond Market." *Journal of Finance*, 61 (2006), 1361–1397.
Hasbrouck, J. "Trading Costs and Returns for U.S. Equities: Estimating Effective Costs from Daily Data." *Journal of Finance*, 64 (2009), 1445–1477.
Helwege, J., and L. Wang. "Liquidity and Price Pressure in the Corporate Bond Market: Evidence from Mega-Bonds." Working Paper, available at ssrn.com/abstract=2801840 (2017).
Hendershott, T.; R. Kozhan; and V. Raman. "Short Selling and Price Discovery in Corporate Bonds." *Journal of Financial and Quantitative Analysis* (2019). doi:10.1017/S0022109018001539.
Hendershott, T.; D. Li; D. Livdan; and N. Schürhoff. "Relationship Trading in OTC Markets." Working paper, available at ssrn.com/abstract=3051859 (2017).
Hendershott, T., and A. Madhavan. "Click or Call? Auction versus Search in the Over-the-Counter Market." *Journal of Finance*, 70 (2015), 419–447.
Ho, T., and H. Stoll. "The Dynamics of Dealer Markets under Competition." *Journal of Finance*, 38 (1983), 1053–1074.
Hollifield, B.; A. Neklyudov; and C. Spatt. "Bid–Ask Spreads, Trading Networks, and the Pricing of Securitizations." *Review of Financial Studies*, 30 (2017), 3048–3085.
Hong, G., and A. Warga. "An Empirical Study of Bond Market Transactions." *Financial Analysts Journal*, 56 (2000), 32–46.
Hotchkiss, E., and T. Ronen. "The Informational Efficiency of the Corporate Bond Market: An Intraday Analysis." *Review of Financial Studies*, 15 (2002), 1325–1354.
Huang, R., and H. Stoll. "The Components of the Bid–Ask Spread: A General Approach." *Review of Financial Studies*, 10 (1997), 995–1034.
Hugonnier, B.; R. Lester; and P. Weill. "Heterogeneity in Decentralized in Asset Markets." Working Paper, available at ssrn.com/abstract=2611084 (2015).
Issa, G., and E. Jarnecic. "Effect of Trading Relationships on Execution Costs in Low Information Asymmetry Over-the-Counter Markets." *Journal of Financial and Quantitative Analysis* (2019). doi:10.1017/S0022109018001485.

Jacobsen, S., and K. Venkataraman. "Does Trade Reporting Improve Market Quality in an Institutional Market? Working Paper, Southern Methodist University (2018).

Jankowitsch, R.; A. Nashikkar; and M. Subrahmanyam. "Price Dispersion in OTC Markets: A New Measure of Liquidity." *Journal of Banking and Finance*, 35 (2011), 343–357.

Jordan, B., and S. Jordan. "Special Repo Rates: An Empirical Analysis." *Journal of Finance*, 52 (1997), 2051–2072.

Kavajecz, K., and D. Keim. "Packaging Liquidity: Blind Auctions and Transaction Efficiencies." *Journal of Financial and Quantitative Analysis*, 40 (2005), 465–492.

Kedia, S., and X. Zhou. "Informed Trading around Acquisitions: Evidence from Corporate Bonds." *Journal of Financial Markets*, 18 (2014), 182–205.

Kim, O., and R. Verrecchia. "Trading Volume and Price Reactions to Public Announcements." *Journal of Accounting Research*, 29 (1991), 302–321.

Kim, O., and R. Verrecchia. "Market Liquidity and Volume around Earnings Announcements." *Journal of Accounting and Economics*, 17 (1994), 41–67.

Krishnamurthy, A. "The Bond/Old-Bond Spread." *Journal of Financial Economics*, 66 (2002), 463–506.

Kwan, S. "Firm-Specific Information and the Correlation between Individual Stocks and Bonds." *Journal of Financial Economics*, 40 (1996), 63–80.

Lee, T., and C. Wang. "Why Trade Over-the-Counter? When Investors Want Price Discrimination." Working Paper, available at ssrn.com/abstract=3087647 (2018).

Li, D., and N. Schürhoff. "Dealer Networks." *Journal of Finance*, 74 (2019), 91–144.

Lin, H.; J. Wang; and C. Wu. "Liquidity Risk and Expected Corporate Bond Returns." *Journal of Financial Economics*, 99 (2011), 628–650.

Loon, Y., and Z. Zhong. "Does Dodd-Frank Affect OTC Transaction Costs and Liquidity? Evidence from Real-Time CDS Trade Reports." *Journal of Financial Economics*, 119 (2016), 645–672.

Lou, D.; H. Yan; and J. Zhang. "Anticipated and Repeated Shocks in Liquid Markets." *Review of Financial Studies*, 26 (2013), 1891–1912.

Madhavan, A.; M. Richardson; and M. Roomans. "Why Do Security Prices Change? A Transaction-Level Analysis of NYSE Stocks." *Review of Financial Studies*, 10 (1997), 1035–1064.

Menkveld, A. "Systemic Risk in Central Clearing: Should Crowded Trades Be Avoided?" Working Paper, available at ssrn.com/abstract=2367287 (2016).

Mizrach, B. "Analysis of Corporate Bond Liquidity." Research Note, FINRA Office of the Chief Economist (2016).

Neklyudov, A. "Bid–Ask Spreads and the Over-the-Counter Interdealer Markets: Core and Peripheral Dealers." *Review of Economic Dynamics*, 33 (2019), 57–84.

O'Hara, M.; Y. Wang; and X. Zhou. "The Execution Quality of Corporate Bonds." *Journal of Financial Economics*, 130 (2018), 308–326.

O'Hara, M., and M. Ye. "Is Market Fragmentation Harming Market Quality?" *Journal of Financial Economics*, 100 (2011), 459–474.

O'Hara, M., and M. Ye. "What's Not There: Odd Lots and Market Data." *Journal of Finance*, 69 (2014), 2199–2236.

Ottonello, G. "The Impact of Benchmarking in Fixed Income Markets." Working Paper, Vienna Graduate School of Finance (2019).

Pan, K., and Y. Zeng. "ETF Arbitrage under Liquidity Mismatch." Working Paper, available at ssrn.com/abstract=2895478 (2017).

Pasquariello, P.; J. Roush; and C. Vega. "Government Intervention and Strategic Trading in the U.S. Treasury Market." *Journal of Financial and Quantitative Analysis* (2019). doi:10.1017/S0022109018001552.

Pastor, L., and R. Stambaugh. "Liquidity Risk and Expected Stock Returns." *Journal of Political Economy*, 111 (2003), 642–685.

Puckett, A., and S. Yan. "The Interim Trading Skills of Institutional Investors." *Journal of Finance*, 66 (2011), 601–633.

Roll, R. "A Simple Implicit Measure of the Effective Bid–Ask Spread in an Efficient Market." *Journal of Finance*, 39 (1984), 1127–1139.

Ronen, T., and X. Zhou. "Trade and Information in the Corporate Bond Market." *Journal of Financial Markets*, 16 (2013), 61–103.

Schaumburg, E., and R. Yang. "The Workup, Technology, and Price Discovery in the Interdealer Market for U.S. Treasury Securities." *Liberty Street Economics*. Available at https://libertystreeteconomics.newyorkfed.org/2016/02/the-workup-technology-and-price-discovery-in-the-interdealer-market-for-us-treasury-securities.html (Feb. 16, 2016).

Schestag, R.; P. Schuster; and M. Uhrig-Homburg. "Measuring Liquidity in Bond Markets." *Review of Financial Studies*, 29 (2016), 1170–1219.

Schlepper, K.; H. Hofer; R. Riordan; and A. Schrimpf. “The Market Microstructure of Central Bank Bond Purchases.” *Journal of Financial and Quantitative Analysis* (2019). doi:10.1017/S0022109018001370.

Schmidt, L.; A. Timmermann; and R. Wermers. “Runs of Money Market Mutual Funds.” *American Economic Review*, 106 (2016), 2625–2657.

Schultz, P. “Corporate Bond Trading Costs: A Peek Behind the Curtain.” *Journal of Finance*, 56 (2001), 677–698.

Schultz, P. “The Market for New Issues of Municipal Bonds: The Roles of Transparency and Limited Access to Retail Investors.” *Journal of Financial Economics*, 106 (2012), 492–512.

Schultz, P. “Inventory Management by Corporate Bond Dealers.” Working Paper, University of Notre Dame (2017).

Schultz, P., and Z. Song. “Transparency and Dealer Networks: Evidence from the Initiation of Post-Trade Reporting in the Mortgage Backed Security Market.” *Journal of Financial Economics*, 133 (2019), 113–133.

Sirri, E. “Report on Secondary Market Trading in the Municipal Securities Market,” Research Paper, Municipal Securities Rulemaking Board, July (2014).

Spatt, C. “Frictions in the Bond Market.” Keynote Speech, Second MTS Conference on Financial Markets (2004).

Spatt, C. “Security Market Manipulation.” *Annual Review of Financial Economics*, 6 (2014), 405–418.

Spatt, C., and S. Srivastava. “Preplay Communication, Participation Restrictions, and Efficiency in Initial Public Offerings.” *Review of Financial Studies*, 4 (1991), 709–726.

Subrahmanyam, A. “A Theory of Trading in Stock Index Futures.” *Review of Financial Studies*, 4 (1991), 17–51.

Trebbi, F., and K. Xiao. “Regulation and Market Liquidity.” *Management Science*, 65 (2019), 1949–1968.

Vickery, J., and J. Wright. “TBA Trading and Liquidity in the Agency MBS Market.” *Economic Policy Review*, 19 (2013), 1–18.

Wang, C. “Core-Periphery Trading Networks.” Working Paper, University of Pennsylvania (2018).

Wang, J.; H. Zhang; and X. Zhang. “Fire Sales and Liquidity Provision in the Corporate Bond Market.” Working Paper, available at ssrn.com/abstract=2644098 (2018).

Wei, J., and X. Zhou. “Informed Trading in Corporate Bonds Prior to Earnings Announcements.” *Financial Management*, 45 (2016), 641–674.

Wu, S. “Transaction Costs for Customer Trades in the Municipal Bond Market: What Is Driving the Decline?” Working Paper, Municipal Securities Rulemaking Board (2018).