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OTC discount

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Non-technical summary

Research Question

When trading among each other, dealers of German sovereign bonds ("Bunds") can trade on an exchange or over-the-counter (OTC). OTC trades are negotiated bilaterally or using the intermediation services of an interdealer broker. Our study investigates how prices of the same security vary across trading venues, the determinants of such pricing differences, and what drives dealers to choose one venue over the other.

Contribution

We use a rich dataset including *all* transactions on Bunds made by financial institutions regulated in Germany between 2011 and 2017 combined with exchange data. We create a measure of relative transaction cost, 'OTC discount', and document that about 85% of OTC transactions trade at conditions that are favourable with respect to the available prices on the exchange. By relating the magnitude of OTC discount to proxies of market frictions (relating e.g. to bargaining power) and information frictions (relating to informedness), we assess the empirical support for leading theories of intermediation frictions in OTC markets. Furthermore, we shed light on the role of brokers in the interdealer market, which facilitate more than three quarters of interdealer volume.

Results

Our evidence suggests that both market and information frictions drive transaction costs and trading decisions in the Bund market, and that each of the three segments plays a unique role for interdealer trading. The exchange provides immediacy and acts as an outside option (a provider of "liquidity of last resort") but is characterized by significant price impact and high transaction costs. Interdealer brokers permit to transact large volumes and provide a high level of opacity as well as having a negligible price impact. Finally, dealers trading bilaterally can achieve the lowest transaction costs and a lower price impact than on the exchange, but face search costs and give up anonymity. While our empirical analysis cannot answer the important question which market structure is socially preferable, our results highlight that theories which address this question may have to consider all of these aspects.

Nichttechnische Zusammenfassung

Fragestellung

Händler (Dealer) deutscher Bundesanleihen können Geschäfte untereinander entweder an einer Börse oder außerbörslich (Over-the-Counter – OTC) abwickeln, wobei der OTC-Handel entweder bilateral oder über einen Interdealer-Broker erfolgt. In unserer Studie wird untersucht, wie die Preise ein- und desselben Wertpapiers je nach Handelsplatz variieren sowie welche Faktoren die Preisunterschiede und die Wahl des Handelsplatzes bestimmen.

Beitrag

Als Grundlage dient ein umfangreicher Datensatz zu den Transaktionen mit Bundesanleihen. Dieser umfasst *sämtliche* Geschäfte, die von 2011 bis 2017 von in Deutschland beaufsichtigten Finanzinstituten getätigt wurden, kombiniert mit entsprechenden Börsendaten. Wir erstellen eine Messgröße der relativen Transaktionskosten, den „OTC-Abschlag" („OTC Discount"), und zeigen, dass rund 85 % der OTC-Geschäfte zu Konditionen abgeschlossen werden, die verglichen mit den an der Börse notierten Kursen günstiger sind. Indem wir die Höhe des OTC-Abschlags mit Näherungsgrößen für die Marktfriktionen (z. B. mit Bezug auf die Verhandlungsmacht) und Informationsfriktionen (im Zusammenhang mit dem jeweiligen Informationsstand) in Beziehung setzen, prüfen wir die empirischen Belege für gängige Theorien über Vermittlungsfriktionen an OTC-Märkten. Darüber hinaus beleuchten wir die Rolle von Interdealer-Brokern, über die mehr als drei Viertel des Volumens im Interdealer-Markt abgewickelt werden.

Ergebnisse

Aus der uns vorliegenden Evidenz geht hervor, dass sowohl Markt- als auch Informationsfriktionen die Transaktionskosten und Handelsentscheidungen am Markt für Bundesanleihen beeinflussen und dass jedes der drei Segmente jeweils eine eigene Bedeutung für den Interdealer-Handel hat. Die Börse ist durch Unmittelbarkeit gekennzeichnet und stellt eine externe Option dar („Liquiditätsgeber der letzten Instanz"), ist allerdings mit einem signifikanten Preiseffekt und hohen Transaktionskosten verbunden. Interdealer-Broker hingegen können große Handelsvolumina abwickeln und gewährleisten ein hohes Maß an Opazität, während die Auswirkungen auf den Preis vernachlässigbar sind. Im bilateralen Handel schließlich sind die Transaktionskosten am niedrigsten und die Preiseffekte geringer als an der Börse, den Händlern entstehen jedoch Suchkosten bei gleichzeitiger Aufgabe ihrer Anonymität. Die wichtige Frage, welche Marktstruktur gesellschaftlich wünschenswert ist, lässt sich zwar anhand unserer empirischen Analyse nicht beantworten, doch deuten die Ergebnisse darauf hin, dass Theorien zu dieser Fragestellung jedem der hier angeführten Aspekte Rechnung tragen müssen.

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OTC Discount

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Abstract

We study price dispersion and venue choice in the interdealer market for German sovereign bonds, where an exchange and over-the-counter segments coexist. We show that 85% of OTC traded prices are favorable with respect to exchange quotes, indicating the prevalence of an *OTC discount*. This discount is sizeable and driven by both search and information frictions. More than 75% of volume is transacted via interdealer brokers in trades that are larger, have less price impact, and less discount than comparable bilateral OTC trades. Dealers trade on the exchange for immediacy, highlighting the complementary roles played by the different segments.

Keywords: Market Microstructure, Hybrid Markets, Venue Choice, Interdealer Brokerage, Fixed-Income, OTC Markets, Intermediation Frictions, Search Frictions, Information Frictions

JEL classification: D4, D47, G1, G14, G24

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I. Introduction

The vast majority of fixed-income cash and derivative markets are over-the-counter (OTC) markets where transactions are based on bilateral negotiations between two counterparties. Prominent examples are the corporate bond and interest rate swap markets. However, for some instruments dealers can also trade among themselves on electronic central limit order books (CLOB) provided by exchange platforms. The interdealer segment of the market for German federal government debt is a case in point, thus providing a unique laboratory to study dealer pricing and trading decisions in a segmented market structure.[1] Understanding the characteristics of the interdealer market is important as it plays a crucial role in helping dealers manage their order flow and provide liquidity to their clients.[2]

German sovereign bonds, generally known as *Bunds*, enjoy benchmark status for Europe as a safe asset and are considered one of the most liquid sovereign bond markets in the world. At the same time the Bund market has become an important gateway for the implementation of monetary policy via the ECB's Public Sector Purchase Program. Combining a unique regulatory dataset that comprises *all* trades involving at least one financial institution regulated in Germany from 2011 to 2017 with the full limit order book of the leading interdealer exchange MTS, we study dealers' pricing and venue choice decisions in interdealer (D2D) Bund transactions. We show that while dealer banks actively trade via the exchange, the vast majority of interdealer transactions in the Bund cash market are dealt over-the-counter, either bilaterally or via interdealer brokers.

Given this segmented structure, we address four key issues pertaining to hybrid markets. We first document the price differences between OTC and exchange trades and highlight the main drivers of these differences. Second, we quantify the contributions of market and information frictions in determining OTC transaction costs. This allows us to assess the empirical support for the leading theories of intermediation frictions in OTC markets. Third, we shed light on the role of interdealer brokers that so far have been largely unexplored in the literature. Fourth, we study the driving forces of dealers' decisions whether to trade on the exchange or in the OTC segment, and whether to trade via a broker or directly with another dealer. As a side contribution we are the first to provide a detailed description of the Bund market microstructure.[3]

The crucial advantage of our empirical setup over related studies is twofold. First, in our setting dealers are active in all segments simultaneously, and not restricted to just one

[1]Securities with a similar market structure are the US Treasury bond market (see, e.g., Barclay, Hendershott, and Kotz, 2006), several other European sovereign bonds (Holland, 2001), foreign exchange, and the index CDS market (Riggs, Onur, Reiffen, and Zhu, 2019; Collin-Dufresne, Junge, and Trolle, 2018).

[2]See (Giancarlo, 2015; Yang and Zeng, 2018).

[3]Upper and Werner (2002) analyze the information content of the Bund futures and cash market. Schlepper, Hofer, Riordan, and Schrimpf (2018) study the effect of central bank purchases on Bund yields, without however providing a detailed description of the Bund cash market.

venue or segment. Second, for any trade we can define the *contemporaneous* conditions of trading on the exchange. This allows us to identify the determinants of price differences by relating them to trade, dealer and bond characteristics.

While several previous studies have analyzed venue choice for equity markets,[4] there is little evidence for bond markets. Two notable exceptions are Barclay, Hendershott, and Kotz (2006), who study the choice between electronic and voice brokerage for U.S. Treasuries that go off-the-run, and Hendershott and Madhavan (2015), who analyze U.S. corporate bonds trading on a request-for-quote (RFQ) platform and OTC. In contrast to these studies, our dataset allows us to directly compare between exchange and OTC trading in a setting consistent with that described in theoretical studies (Seppi, 1990; Grossman, 1992; Lee and Wang, 2017).

The observed price differences between exchange and OTC trades allow us to calculate our main quantity of interest, *OTC discount*, which measures the discount of an OTC trade with respect to potential execution of the same trade on the exchange at the same time. A positive OTC discount corresponds to cheaper execution in the OTC segment.[5] Our main finding is that the vast majority of transactions in the D2D segment trades at a lower price than the one attainable on MTS, in line with predictions from models of adverse selection (Seppi, 1990; Lee and Wang, 2017) and reflecting the cost of immediacy of market orders on the exchange (Zhu, 2014; Menkveld, Yueshen, and Zhu, 2017). Specifically, about 85 percent of OTC trades feature a discount relative to the price at which the same security would be traded on the exchange at the same time. On average, the OTC transaction cost for trades between dealers is about 33 percent lower than the corresponding cost on MTS.

The theoretical literature concerned with modelling OTC markets points to the role of market frictions (related to inventory, search costs, and bargaining power; see, e.g., Stoll (1978); Duffie, Gârleanu, and Pedersen (2005), and, especially in the context of hybrid markets, information frictions (see, e.g., Seppi, 1990; Lee and Wang, 2017; Babus and Kondor, 2018). We quantify the contributions of both channels to OTC discount by relating it to measures of dealers' informedness and market frictions. We find that both channels are quantitatively important drivers of OTC discount. More informed bilateral OTC trades receive significantly lower discounts. At the same time, traders with more bargaining power receive higher discounts.

[4]Examples include Madhavan and Sofianos (1998); Smith, Turnbull, and White (2001); Bessembinder and Venkataraman (2004); Carollo, Vaglica, Lillo, and Mantegna (2012).

[5]Cenedese, Ranaldo, and Vasios (2019) use a similar terminology in their analysis of interest rate swaps. These contracts are traded in an OTC market, where some of these trades are cleared via central counterparties (CCP) and others are not. They document that the same derivative contract is more expensive when it is not cleared via a CCP, and label these price differentials OTC premia. They attribute such premia to regulatory requirements to hold more capital for trades that are not cleared via a CCP, as these are subject to counterparty risk. In our setting there is no such risk and the discount refers to the difference between quoted prices on the exchange and transaction prices of OTC trades.

More than 75 percent of Bund interdealer volume is traded via interdealer brokers. These intermediaries provide opacity, as there is no dissemination of post-trade information, and anonymity, since dealers are unaware of the identity of their counterparty.[6] We present three sets of results that help understand the specific role and functioning of brokers. First, we find that market frictions determine OTC discount to a similar extent for broker trades as for bilateral OTC trades, but we find no such evidence for proxies of information frictions in broker trades. Second, using a matched sample of otherwise similar bilateral and broker-facilitated transactions, we show that the latter feature significantly higher transaction costs than bilaterally negotiated OTC trades. Taking into account trade, bond, and dealer characteristics, this difference amounts to about one-third of the discount in bilateral trades. Third, we measure price impact as the average reaction of mid-prices on the exchange to trades over a horizon of up to one hour, and show that broker trades have essentially no such price impact, while bilateral and especially exchange trades do. These results suggest that interdealer brokers allow dealers to trade with each other while at the same time concealing their order flow and protecting themselves against price revision risk (Naik, Neuberger, and Viswanathan, 1999) and frontrunning (Harris, 1997; Brunnermeier and Pedersen, 2005). Consistent with this interpretation, we see that particularly large, and thus central, dealers prefer to trade with each other via brokers instead of bilaterally. Our observations are in line with the finding in Hagströmer and Menkveld (2019), that strongly connected central FX dealers are more informed, and with Anderson and Liu (2019), who find that the usage of interdealer brokers by dealers in the U.S. Treasury market increases with interest rate risk. However, our findings contrast with those in Barbon, Di Maggio, Franzoni, and Landier (2019) and Di Maggio, Franzoni, Kermani, and Sommavilla (2019), who document that equity brokers leak private information from informative trades to their institutional clients.

Given the dispersion of trade prices and their driving forces, we further study dealers' venue choice between trading on the exchange, bilaterally or via brokers. We first estimate a probit model for the probability that a dealer will perform a given trade on the exchange instead of over-the-counter depending on the trade's characteristics. Second, for OTC trades we estimate a probit model for whether a dealer will route a given trade via a broker instead of negotiating bilaterally. We find that trade size is the main driver of these decisions, creating a "pecking order" in size where trading activity shifts from the exchange to bilateral negotiations to broker facilitation as the traded amount increases. Moreover, trading on the exchange is more likely (i) when trades are informed, i.e. for trades with larger price impact and as part of order splitting strategies, (ii) when demand

[6]Broker trades share similarities with dark pool trading. For a recent overview of the extant literature on dark pools we refer to Menkveld, Yueshen, and Zhu (2017). The major difference in our setting is that interdealer brokers operate price discovery protocols that differ from, e.g., midpoint protocols popular for dark pools, and that we compare interdealer brokerage not only to exchange trading but also to bilateral OTC activity.

for immediacy is high, i.e. on days with high intraday volatility, and (iii) for assets with wider bid-ask spreads, i.e. Bunds with very long maturities and Bunds not closely linked to a futures contract.

In sum, our evidence suggests that both market and information frictions drive transaction costs and trading decisions in the Bund market, and that each of the three segments plays a unique role for interdealer trading. The exchange provides immediacy and acts as an outside option (a provider of "liquidity of last resort") but is characterized by sizable price impact and high transaction costs. Interdealer brokers permit to transact large volumes and provide a high level of opacity as well as a negligible price impact. Finally, dealers trading bilaterally can achieve the lowest transaction costs and a lower price impact than on the exchange but face search costs and give up anonymity. The importance of information frictions in bilateral OTC trades is striking since Bunds arguably represent a safe asset (Gorton, 2017). Hence, even in the absence of private information about fundamental asset values, information about order flow may play an important role (Burdett and O'Hara, 1987; Colliard and Demange, 2018). This suggests that, in a setup like ours, information frictions relate less to concerns about adverse selection but rather to the reluctance of dealers to expose their trading interests (Harris, 1997; Naik, Neuberger, and Viswanathan, 1999; Brunnermeier and Pedersen, 2005).

Our analysis is relevant in light of current policy debates and regulatory changes. There is a strong effort to improve OTC market transparency both in Europe, where the MiFID II regulation was recently rolled out with the intention to improve market conditions in and beyond European markets,[7] and in the U.S., where FINRA has started to collect data similar to that in the TRACE database also for sovereign bonds. In this paper, we analyze the incentives of traders faced with venue choices and highlight important differences in execution prices. Our results suggest that OTC and exchange as well as broker-intermediated trading play complementary roles in serving the different needs of dealers in a way that a single venue might not be able to achieve. While our empirical analysis cannot identify which market structure would be socially optimal, our results provide insights for theoretical studies addressing this important question and for the regulation of fixed-income trading.

The remainder of this paper proceeds as follows. Section II describes the Bund market and our dataset. Section III introduces the measurement of our main quantity of interest, OTC discount. Section IV relates OTC discount to theories of market frictions and price discrimination. In Section V we explore the drivers of OTC discount, both for bilateral and broker-intermediated OTC trades. Section VI studies the venue choice between trading

[7]Since January 3, 2018, Directive 2014/65/EU - Markets in Financial Instruments Directive II (MiFID II) has been effective for all European markets. It includes provisions for pre- and post-trade transparency, separation of transaction and related services fees, and mandatory best execution among others. Our sample period ends before the introduction of MiFID II.

on the exchange and over-the-counter and between bilateral and broker-intermediated OTC trading. Section VII concludes.

II. The Bund Market

A. Market Structure

German sovereign debt securities enjoy benchmark status in the Eurozone and worldwide as a liquid and safe asset. They are issued as 6- or 12-month zero coupon Treasury discount papers ("Unverzinsliche Schatzanweisungen", *Bubills*), 2-year "Bundesschatzanweisungen" (*Schaetze*), 5-year "Bundesobligationen" (*Bobls*) and 10- and 30-year "Bundesanleihen" (*Bunds*).[8] In this study we focus on titles with longer maturities, i.e. 2-year Schaetze, 5-year Bobls and 10- and 30-year Bunds, and, where not explicitly mentioning maturities, we intend all of them when referring to Bunds from here on.

German government securities are issued regularly by the German finance agency ("Deutsche Finanzagentur", *DFA*) either as new issues or as reopenings of already issued bonds.[9] For this reason, on-the-run effects, which exist, e.g., for U.S. Treasury bonds, are negligible in the Bund market, and we include both on-the-run and off-the-run Bunds in our analysis. Participants in this primary market are the members of the *Bund Issues Auction Group*, a group of currently 36 international banks that commit to subscribing to a certain minimal amount of the total annual issuance.[10]

A survey by DFA among Bund Issues Auction Group members pegs daily trading volume in the secondary (*cash*) market at more than 17 billion EUR.[11] In this study our focus is on the interdealer (D2D) segment of the market, which features three distinct trading protocols. First, dealers can trade directly with each other in bilateral over-the-counter negotiations. These bilateral trades are typically only observed by the two dealers involved, but not by the rest of the market. Second, dealers can trade with each other via interdealer brokers. In the case of trading via a broker, the initiating dealer

[8] There are also inflation-linked Bobls and Bunds, which we do not consider in this study. We likewise do not consider any regional issued debt, such as *Laender* bonds or debt titles from supranationals with a federal guarantee, e.g. by Kreditanstalt für Wiederaufbau (KfW).

[9] In reopenings, the amount outstanding of a previously issued bond is increased while its characteristics (such as coupon rate and maturity date) remain unchanged.

[10] Auction days are announced well in advance, and the tender process runs from 08:00 until 11:30 a.m. CET on the day of the auction, after which the allotment decision is made immediately and the results are published. Auction group members can place competitive and non-competitive bids. The former are allotted in full at the bid price up to the lowest accepted price and the latter at a weighted average price of the accepted competitive bids. For more details regarding the auction process, auction schedule, members of the Bund Issues Auction Group, and auction results, we refer to the DFA website: `https://www.deutsche-finanzagentur.de/en/institutional-investors/primary-market/`.

[11] These numbers (see `https://www.deutsche-finanzagentur.de/en/institutional-investors/secondary-market/`) are in line with hand-collected statistics from MiFID II reporting. Our sample captures about 15% of this trading activity.

communicates their trade request to a broker, who then undertakes to find a suitable counterparty. Crucially, the broker acts as a matched principal and the dealers involved are thus unaware of the identity of the counterparty to the trade.[12] As with bilateral trades, also broker trades are unobserved by other market participants. Conversations with practitioners (see also Holland, 2001) suggest that large dealers avoid trading directly with each other and instead prefer to use the services of interdealer brokers. The third option for dealers to trade with each other is via an exchange. While several trading platforms exist alongside the over-the-counter segment, most of them are aimed at the retail segment of the market. A crucial exception is the interdealer exchange MTS, which is operated as a fully electronic limit order book market.[13] During the hours from 9 a.m. to 5:30 p.m. CET dealers actively quote executable limit orders on MTS, and the depth on both the bid and ask side of the book is typically in excess of 100 million EUR for most bonds, while the minimum trade size is 2 million EUR. This, in conjunction with the availability of MTS data for market participants and researchers, has given MTS a benchmark function for European sovereign bond markets.[14] Unlike bilateral and broker-facilitated OTC trades, all trading activity on the exchange is observed by all market participants. Regardless of trading protocol, cash trades are settled via repositories, so that there is essentially no counterparty risk.

This segmented structure is not unique to the interdealer Bund market, but is very similar, e.g., to the UK Gilt market (Holland, 2001). In the U.S. Treasury market (Fleming, 1997; Fleming and Remolona, 1999; Mizrach and Neely, 2009) the order book of the BrokerTec platform takes a role similar to MTS. On the BrokerTec platform size-discovery protocols such as the "work up" described in Duffie and Zhu (2017) and Fleming and Nguyen (2018) are heavily used. On MTS similar protocols exist, but play a negligible role.[15]

[12]See, e.g., the AFME European Primary Dealers Handbook part 17.6, available at `https://www.afme.eu/en/reports/publications/european-primary-dealers-handbook-q3-2017/`.

[13]Some other platforms (e.g. Brokertec and Tradeweb) also show some interdealer trading activity, but their market share is negligible.

[14]Dufour and Skinner (2004) provides a detailed description of the MTS dataset and Darbha and Dufour (2013) give an overview over market structure and liquidity. The list of MTS participants, available in its current version at `www.mtsdata.com/content/data/public/gem/anagraph/member.php`, largely overlaps with the members of the Bund Issues Auction Group. Note that MTS participants must be banks, thus barring, e.g., hedge funds from accessing the trading venue. MTS data has been used and validated in numerous studies at the European level, an incomplete list of which includes Beber, Brandt, and Kavajecz (2009); Pelizzon, Subrahmanyam, Tomio, and Uno (2016) and Schneider, Lillo, and Pelizzon (2018).

[15]Even though provisions for midpoint matching are in place on MTS, the mechanism is only very sporadically used by participants, and we have verified that it does not impact our results. Iceberg orders are allowed on MTS, but are also rarely used or executed. Further differences between the MTS and BrokerTec platforms are a) the number of bonds traded (in BrokerTec 6 on-the-run U.S. Treasury bonds are traded compared to about 60 Bunds on MTS), and b) the set of participants (36 dealer banks on MTS compared to around 100 participants on BrokerTec, including dealers, hedge funds and high-frequency trading firms).

In addition to the cash market, there exist futures contracts for 2-year Schaetze, 5-year Bobls and 10-year and 30-year Bunds, with most activity in the 10-year Bund futures. Turnover across all futures was almost 32 trillion EUR in 2017, more than seven times the turnover in the cash market, with a minimum size of 100,000 EUR and minimum tick sizes corresponding to $0.5 - 2$ basis points depending on the contract.[16] It is worth pointing out that *physical delivery* of the futures on the delivery day is rare and most contracts are closed by entering an opposite position. This implies that, notwithstanding the comparatively more active futures market, anyone wanting to own Bunds, e.g. for regulatory reasons or to enter an arbitrage position, needs to be active in the cash market.

B. Data Sources

Our study is based on a unique regulatory dataset of trades by German financial institutions which we link to the full limit order book data from the interdealer exchange MTS. Our observation window spans from June 1st, 2011 through December 31st, 2017.

The regulatory transactions data is based on reporting requirements of German financial institutions to the German Federal Financial Supervisory Authority (Bundesanstalt für Finanzdienstleistungsaufsicht, popularly known as "BaFin") and mandated by the German Securities Trading Act ("Wertpapierhandelsgesetz") and the respective regulation ("Wertpapierhandel-Meldeverordnung"). We refer to this dataset as *transactions data*. It includes any transaction by the reporting institutions in a wide set of securities, including German government bonds, and contains information on the price, size and time of the trade, a flag indicating whether a trade was over-the-counter or the platform in which the trade was executed as well as an indicator whether a trade was a buy or a sell from the point of view of the reporting institution. Further, we obtained anonymized identifiers for the reporting agent and the counterparty of a trade, where the identifier for the counterparty can be missing when the counterparty has no regulatory requirement to the German Federal Financial Supervision.[17] The transactions data does not include information on who initiated the trade. Hence, we infer the initiator of each trade by comparing the

[16]Trading activity is generally concentrated in the contract with the nearest delivery day, which is around the 10th of each March, June, September and December. Between three and five bonds are *deliverable* for each contract, one of them being the *cheapest-to-deliver*. Its price is thus closely tied to the one of the futures via an arbitrage relationship. Contractual details for the futures can be found at `http://www.eurexchange.com/exchange-en/products/int/fix/government-bonds/Euro-Bund-Futures/14770`. Trading hours last from 8 a.m. to 10 p.m. CET and thus exceed those of MTS. Due to the low interest and coupon rates prevalent during our sample period, the cheapest-to-deliver bond almost always coincided with the eligible bond with the nearest maturity date.

[17]For a detailed description of the dataset, including initial data cleaning procedures, we refer to Gündüz, Ottonello, Pelizzon, Schneider, and Subrahmanyam (2018) and the text of the law and regulation, for which a non-binding English translation is provided at `https://www.bafin.de/SharedDocs/Veroeffentlichungen/EN/Aufsichtsrecht/Gesetz/WpHG_en.html` (Section 9 therein) and `https://www.bafin.de/SharedDocs/Veroeffentlichungen/EN/Aufsichtsrecht/Verordnung/WpHMV_en.html?nn=8379960` respectively.

trade price to the contemporaneous mid-price on the exchange as in Bessembinder and Venkataraman (2004) and Eisler and Bouchaud (2016).[18]

Our dataset from the interdealer exchange MTS contains all trades as well as the full limit order book information on all executable quotes. We obtain bond characteristics from Bloomberg and Thomson Reuters Eikon as well as auction results published by the German finance agency. We match trades from the transaction dataset to the MTS limit order book at one minute precision. This corresponds best to the effective resolution of the transactions data, and we have performed extensive robustness checks to determine the optimal frequency and rule out potential lead or lag effects in the data. We have also ensured agreement of timestamps for exchange trades that we observe both in the transactions dataset and via our MTS data.

C. Trading Activity

Table I describes the trading activity covered by our sample and relevant subsamples in terms of number of trades, aggregate trading activity, statistics of trade size, and market share by type of trading venue. Our full sample contains over 500,000 trades across 116 German federal bonds and 402 reporting institutions (labeled "full sample").[19] Most of these trades are for very small amounts. To identify trades where there is an actual choice between trading over-the-counter and on the exchange, we limit our sample to the set of trades where trading in both venues is a viable option. Specifically, we only consider trades for a nominal amount of at least 2 million EUR, the minimum size requirement of MTS (labeled "trade size $\geq$ 2 million EUR"). While this reduces the number of observations to about 200,000, they still represent 3.27 trillion EUR or 96% of the overall reported trading volume in our full sample.

To compute our quantities of interest we require further knowledge on the initiator and counterparty to a trade. This information may be unavailable, either when a party to a trade is not identified in the transactions data, or when the trade sign is undefined, e.g. for trades at exactly the MTS mid-price or outside of MTS trading hours. For 103,619 trades worth 1.52 trillion EUR we can identify both initiator and counterparty (labeled "init. & counterp. ID known"). The latter sample corresponds to roughly half the initial selection of trades with a minimum size of 2 million EUR.

Out of this sample with complete initiator and counterparty information, there are 25,955 interdealer trades (by 34 dealers and via 6 interdealer brokers) worth a total

[18]Whenever the observed trade price is above (below) the mid-price of MTS at the full minute preceding the transaction, the trade is identified as buyer- (seller-) initiated. We do not assign a trade sign to trades at the mid-price (about 3% of our sample), thus differing from the approach in Lee and Ready (1991).

[19]Reporting institutions are the ones for which the German Securities Trading Act is binding. One bank group might report using more than one reporting institution ID, e.g. in the case of foreign dependencies. Including counterparties identified by an ID there are 1,297 entities in our sample, while for some (e.g. non-German) counterparties this ID is missing.

of 479.49 billion EUR (labeled as "D2D"). Our definition of *dealers* is based on MTS membership, i.e. we consider as dealers only those dealer banks that are active on the interdealer exchange, thus excluding, e.g., some primary dealers that forego MTS membership or dealers that are MTS members but never trade thereon. Focusing on this sample in our subsequent analysis, we ensure that both parties of the trade have access to the MTS exchange market beyond the OTC segment. The average trade size in this sample is 18.47 million EUR, and more than 25% of interdealer trades are larger than 25 million EUR.[20] 2,428 interdealer trades take place on the exchange MTS (labeled "D2D via MTS", corresponding to 3.7% of interdealer volume), while there are 8,328 OTC transactions resulting from bilateral negotiations ("D2D bilateral OTC") that account for 18.8% of overall interdealer volume in our sample. The biggest share of interdealer trading is due to trades via brokers ("D2D via broker (D2B)"), both in terms of number of trades (15,199) and overall volume, where broker trades account for 77.5%.[21]

The average nominal trade size in the interdealer segment increases from 7.30 million EUR on MTS, to 10.83 million EUR in bilateral OTC transactions to 24.45 million EUR in trades via brokers. A comparison of the percentile values indicates that these differences are primarily due to a higher share of very large trades via brokers.

III. Measuring OTC Discount

In this section, we study transaction cost differences between the OTC and exchange segments of the Bund market. Theories of hybrid markets based on information frictions generally predict lower transaction costs in the OTC than in the exchange segment. For example, in the model of Lee and Wang (2017) liquidity providers price discriminate in the OTC segment by favoring uninformed investors, whereas on the exchange they set wider quotes in order to avoid being adversely selected. Furthermore the bid-ask spread on the exchange reflects the cost of immediacy of a market order, which is greater than for requests for quotes in an OTC setting. Accordingly, the spread on the exchange is higher than the OTC spread.

A common approach to estimate transaction costs in OTC markets is via proxies estimated over multiple trades such as, e.g., the imputed round-trip cost, price dispersion or effective bid-ask spread measures (Schestag, Schuster, and Uhrig-Homburg, 2016), whereas in hybrid settings it is common to compare prices adjusted for the venue choice (Madhavan and Cheng, 1997; Hendershott and Madhavan, 2015). In our setting, given that we focus on the same subsample of dealers that trade both OTC and on the exchange,

[20] The latter observation is in line with evidence presented by MiFID II reports and affirms the representativeness of our sample for the total market.

[21] We observe a small number of interdealer trades on other platforms, accounting for only 0.3% of interdealer volume. Our results are robust to excluding these trades from our sample.

the presence of contemporaneous limit order data from MTS allows instead for a direct comparison of the cost of OTC trades with attainable exchange prices at the level of individual trades.

We define the *OTC discount* that a trader is facing when initiating a trade as the difference in price between the virtual price a trade would have incurred on the exchange and the observed price of an OTC trade, symmetrized for the direction of the trade and normalized by the respective virtual transaction cost on the exchange. More formally, we define OTC discount as:

$$OTC\ discount = \frac{\epsilon \left(price^{\text{virtual,MTS}} - price^{\text{observed, OTC}} \right)}{\left\| price^{\text{virtual,MTS}} - price^{\text{mid,MTS}} \right\|} \quad , \tag{1}$$

where $price^{\text{observed, OTC}}$ is the price of an over-the-counter trade observed in our transaction data and $price^{\text{virtual,MTS}}$ is a virtual price which the same trade would have incurred on MTS at the same time. $price^{\text{mid,MTS}}$ is the MTS mid-price at the time of the trade. The trade sign ϵ is $+1$ (-1) for buyer- (seller-) initiated trades and inferred by comparing to the contemporaneous MTS mid-price. As the reference price we use the quoted price at the respective best level of the limit order book, i.e. $price^{\text{virtual,MTS}}$ is the best ask (bid) price for buyer- (seller-) initiated trades, thereby disregarding that larger trades would have to execute also against quotes at deeper levels of the limit order book ("walking up the book"). We do so since such large trades are rare on MTS and the price at the best provides a better benchmark for OTC trades than an "effective" price. The denominator in Equation (1) is equal to the quoted half-spread on MTS and by our trade sign identification OTC discount is bounded from above by 100%. Since the discount of MTS trades is by definition equal to zero, we only consider the OTC discount of over-the-counter trades and trades on platforms other than MTS in this section.

Figure 1 illustrates the trade sign identification and calculation of OTC discount. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. We refer to an *OTC premium* when OTC discount is negative, i.e. when it would have been cheaper to trade on MTS instead of OTC.

In Table II we provide the descriptive statistics of OTC discount. Both mean and median of OTC discount are positive across all considered trade subsamples, and on average the OTC discount is equal to 33.4% for interdealer trades, i.e. dealers pay on average just about two thirds of the quoted MTS bid-ask spread when trading among each other. The share of interdealer trades with an OTC premium is 15.0%. For all reported samples we reject the null hypothesis that the average OTC discount is zero at a 0.01% significance level.

The distributions of OTC discount are quite similar for the different trade samples in the top rows of Table II. Notable exceptions are interdealer trades concluded through bilateral negotiations or via brokers. Bilateral OTC trades receive a much larger average discount of 48.0% as opposed to, on average, 25.4% via brokers. Bilateral trades also have a lower share of trades with an OTC premium: 7.3% as opposed to 19.3% for trades via brokers.[22] Figure 2 shows the histogram of OTC discount for these samples, i.e. for interdealer trades with a minimum size of at least 2 million EUR, where Panel (a) refers to bilaterally negotiated trades and Panel (b) is based on transactions via brokers. Both subsets feature a distribution that is heavy on positive values of OTC discount, i.e. in the majority of cases, trading over-the-counter is cheaper than on the exchange. However the distribution for bilateral trades is more right-skewed, while broker trades have a wider distribution and feature far more instances of OTC premia or trade exactly at the MTS best.

To attest that our results hold irrespective of this definition of OTC discount, we present several robustness checks in the Appendix. First, we explicitly account for the effects of large trades walking up the book, i.e. $price^{\text{virtual,MTS}}$ is no longer the price at the best, but the actual price that would result for a trade of a given size given the current state of the limit order book. Furthermore, we mitigate size issues by repeating our analyses on samples limited to trades for a nominal amount of at most 25 million EUR, where liquidity in the MTS order book is still sufficient. Second, in order to relate to yields instead of transactions costs, we consider an alternative definition of OTC discount where we normalize by price instead of transaction cost, i.e. the denominator in Equation (1) becomes $price^{\text{mid,MTS}}$. Our results are robust with respect to these alternative definitions.

Our results are different from those of similar studies with hybrid settings that involve OTC segments and electronic request-for-quote (RFQ) platforms. There, trading costs are typically lower for client-to-dealer trades in the RFQ segment, as documented by Hendershott and Madhavan (2015) for U.S. corporate bonds and Hau, Hoffmann, Langfield, and Timmer (2019) for foreign exchange derivatives. These results are consistent with Vogel (2019), who develops a theoretical model for such a setup and studies when the introduction of RFQ platforms is able to improve welfare over pure OTC markets.[23] Instead, Dunne, Hau, and Moore (2015) find that prices of client-to-dealer trades in European sovereign bonds via a RFQ platform are mostly favorable with respect to the limit order book of the interdealer exchange MTS, without however considering the OTC segment of the interdealer market that is our focus. In the interdealer market for index CDS studied by Collin-Dufresne, Junge, and Trolle (2018), dealers cannot only trade in a limit order book, but also using a mid-market matching or a workup protocol. They find that transaction costs (and price impacts) are lower for the latter two protocols than

[22] The larger share of OTC premia for broker trades relates also to their, on average, larger size. In the Appendix we show that, when including the effects of trades walking up the book, the share of trades with an OTC premium is 6.0% and 13.0% for bilateral and broker-facilitated OTC trades respectively. Other motives for trading at an OTC premium include trading relationships and the need for opacity.

[23] Also Dugast, Üslü, and Weill (2019) study welfare in a setting where dealer banks, depending on their trading capacity and risk sharing needs, participate in a centralized market, in an OTC market, or in both.

for the limit order book, in a setup quite similar to equities markets with dark pools as studied in Menkveld, Yueshen, and Zhu (2017) and modeled in Zhu (2014). Our study is different, a) since we compare pricing of OTC trades to an exchange with a limit order book, in line with theoretical studies of hybrid markets such as Seppi (1990); Grossman (1992); Lee and Wang (2017); and b) in that we focus on the interdealer segment, where we are able to observe differential pricing involving the same set of actors across segments. The hybrid structure of our setting is also different from the mid-market matching and workup protocols analyzed in Collin-Dufresne, Junge, and Trolle (2018).

IV. Market and Information Frictions

In this section, we discuss how market and information frictions may affect OTC discount and venue choice. We introduce measures that represent the information, search and inventory channels in our hybrid market structure and discuss their potential role based on theoretical models of over-the-counter and hybrid markets.

A. Frictions and Proxy Variables

Market frictions. Search-based models of over-the-counter markets identify bargaining power as the crucial driver of OTC transaction costs. They predict that dealers with more bargaining power face lower transaction costs (Duffie, Gârleanu, and Pedersen, 2005, 2007; Duffie, 2012). Here we apply these predictions to the OTC segment of our hybrid setting. Specifically, we relate dealers' bargaining power to the availability of outside options, their order flow relative to prevalent market conditions, and their relationship to other dealers.

Duffie, Gârleanu, and Pedersen (2005) argue that access to outside options increases dealers' bargaining power. In our setting, dealers engaging bilaterally with a counterparty have the outside options to trade on the exchange or to search for another counterparty, among others. Since large trades become increasingly expensive on MTS, this outside option diminishes with increasing trade size. We capture this with the variable *Trade size*, measured in logarithmic scale. Similarly, a trader requiring immediacy may be unable to invest time searching for other counterparties, effectively reducing her outside options from continued search. We proxy immediacy through a dummy variable that indicates particularly volatile bond-days as in Zhu (2014). That is, the dummy variable *Volatility* indicates the 10% most volatile bond-days in our sample.

Next, we relate bargaining power to the direction of order flow relative to the market. For example the model of Colliard, Foucault, and Hoffmann (2018) features a core-periphery structure where dealers' bargaining power and price dispersion depends on the aggregate positions in the core and periphery of the market, among other factors. A dealer buying (selling) a Bund is in a better (worse) bargaining position when there is selling pressure in the market. We use two proxy variables that capture the net order flow of the market, one based on OTC transactions and the other based on the imbalance of the limit order book. *Aggregate Order Flow* captures the net order flow of all OTC trades, including customer trades, in all Bunds prior to the trade on that day. It is positive when trading in the same direction as the market. *Order Book Imbalance* captures the contemporaneous imbalance between the best three levels on both sides of the limit order book of the same Bund and is also defined positive when trading in the market direction that is implied by the order book imbalance.

Several studies have identified the dealer network structure and trading relations as important factors for pricing in OTC markets, e.g. for corporate bonds (Di Maggio, Kermani, and Song, 2017; Hendershott, Li, Livdan, and Schürhoff, 2017) and municipal bonds (Li and Schürhoff, 2019), in line with theoretical studies such as Glode and Opp (2019). First, more central dealers benefit from their position and are able to charge higher markups. Second, markups are lower in established trading relationships, and especially so in times of turmoil (see also Glode and Opp, 2016). Unfortunately, since we observe only trades involving German financial institutions, we are unable to reconstruct the full network of interdealer trading. We thus do not consider network measures in our analysis. Instead, we rely on the overall trading volume of a dealer (*Dealer Volume*) to distinguish between large and small dealers, or we use dealer-fixed effects which capture differences in centrality and individual bargaining power. Another reason is that in the Bund market large dealers very rarely trade with each other directly but rather on the exchange or via brokers. Relationship and centrality might therefore be less meaningful in our setting than for other OTC markets, even if we were able to observe the full network of trading activity.

It is well established that dealers' inventory influences trading decisions and asset prices (see ,e.g., Stoll, 1978; Amihud and Mendelson, 1980; Ho and Stoll, 1981, 1983; Friewald and Nagler, 2018). Dealers adapt their bid and ask quotes in order to balance inventory positions or would accept to pay (receive) a higher (lower) price in order to reduce their inventories. We use the variable *Inventory Imbalance* to capture the dealer's net inventory of Bunds relative to the trading direction. It is calculated from the transactions data as the net imbalance of the dealer from trades in the same bond on the same day prior to the trade. For example, for a trade reducing a dealer's inventory position the variable is negative.

Information Frictions. Information-based theories of hybrid markets typically distinguish between uninformed (liquidity-motivated) traders and informed traders (see ,e.g., Seppi, 1990; Lee and Wang, 2017). In the model of Lee and Wang (2017), liquidity providers are able to (imperfectly) infer the information state of their counterparties (via their "reputation"). Assuming that liquidity providers are able to infer information at the level of single trades, we identify trades with larger price impact as more informed. Following Collin-Dufresne, Junge, and Trolle (2018), we capture this empirically by using the 15-minute-ahead price impact of each trade as an ex-post estimator of informedness (*Price impact (15min)*).

In Seppi (1990), equilibria emerge where liquidity traders always prefer to trade large blocks over-the-counter, whereas informed traders mix between said block strategy and splitting up their order into a series of smaller trades. Therefore, as our second proxy of informedness, we consider the dummy variable *Order splitting* that indicates whether a trade is the result of order splitting. We identify order splitting when a dealer has multiple trades of the same bond in the same direction on a given day. Detailed definitions of all proxy as well as control variables are provided in Table III along with their descriptive statistics in Table IV.

B. Predictions for OTC Discount

In this section we discuss how market and information frictions should affect OTC discount according to the theories above. Since most theoretical predictions are for bilaterally negotiated trades, we focus on the OTC discount of such trades. We discuss the implications for broker-facilitated OTC trades thereafter.

B.1. Predictions for OTC Discount in Bilateral OTC Trades

Market frictions. Dealers with more bargaining power are predicted to have lower transaction costs, i.e. higher OTC discounts. A reduced availability of outside options implies less bargaining power and therefore lower OTC discounts. Hence we expect a negative relationship between trade size (reduced outside option of trading on the exchange) and OTC discount, and a negative relationship between high volatility (reduced outside options from continued search) and OTC discount. Moreover, bargaining power relates to the aggregate order flow. Trading in the same direction as the market lowers bargaining power and should thus reduce OTC discount. Our proxy variables for aggregate order flow, *Aggregate order flow* and *Order book imbalance*, are defined as positive when trading in the same direction of the market. We therefore expect a negative relation with OTC discount, i.e. trading in the same direction as the market is more expensive.

Given the benefit of a trade offsetting inventory imbalance, a dealer should be willing to accept a lower discount for such trades. Since *Inventory imbalance* is defined as negative for offsetting trades, we thus expect a positive relation with OTC discount.

Individual bargaining power. We also include fixed effects for individual dealers in our regressions of OTC discount. These fixed effects capture differences that remain after controlling for market and information frictions, as well as other trade characteristics and controls. We conjecture that these relate to the individual bargaining power of dealers beyond the factors captured by our other proxy variables. Since, for example, we do not control for network centrality, it will likely be reflected in the fixed effects. Fixed effects that are significant and large in magnitude likely indicate differences in the individual bargaining power of dealers, thus highlighting the importance of the search channel.

Information frictions. In Lee and Wang (2017), dealers "cream-skim" the order flow from uninformed investors on the over-the-counter market by offering a lower bid-ask spread to investors deemed uninformed. This reflects the intuition of Kyle (1985) that a liquidity provider on the exchange needs to quote a wider bid-ask spread to insure herself against the risk of being adversely selected by informed traders, which is not the case in the OTC segment that allows a filtering of counterparties. Therefore, we expect informed trades, proxied by their larger price impact and the occurrence of order splitting, to have lower OTC discount, as predicted also in Seppi (1990). Somewhat in contrast, Babus and Kondor (2018) link network centrality to informedness. Because central dealers trade more, they are better informed. Naik, Neuberger, and Viswanathan (1999) also point out the importance of this information acquisition channel for trading. If such an effect were dominant, more informed trades should receive higher discounts.

B.2. Predictions for OTC Discount in Broker Trades

Unfortunately, theory is largely silent about the role of interdealer brokers for trading. With the exception of Duffie and Zhu (2017), who focus on a particular size discovery mechanism, the "work up", we are unaware of theoretical work to model the trading protocols and mechanisms used by brokers in contexts and markets similar to ours. We therefore focus on two distinctive features of interdealer brokerage with respect to other trading protocols that might play a role for OTC discount.

First, like bilateral OTC trades, broker trades involve a search process. Given that our proxies for market frictions mostly relate to the concurrent trading environment (e.g. demand for immediacy or buying/selling pressure in the market), we expect that these play a similar role for broker-facilitated trades as for bilateral OTC trades.

However, a relevant difference may be that the search process is undertaken by a broker instead of the dealer itself. Due to their business model and, crucially, the opacity and anonymity they provide, it is likely that brokers have a better understanding of and a privileged access to the unexpressed order flow of dealers, and thus have an advantage to matching trading interests among dealers. Since in equilibrium a marginal trader will be indifferent between paying a higher search cost and receiving a higher discount in bilateral trading, or spending less search cost and receiving a lower discount via a broker, we expect that OTC discount is lower for broker trades from a search cost point of view.

Second, interdealer brokerage, unlike bilateral trading, provides anonymity of counterparties. In bilaterally negotiated OTC trades both parties are aware of each other's identity, and thus able to price discriminate against each other based on the perceived informedness of the counterparty. When trading through a broker, both sides are typically unaware of the other's identity, which is protected by the broker. That is, the broker provides opacity, both in terms of preserving anonymity of involved traders from each other and in terms of post-trade transparency, since trades are not publicly reported.[24] Hence, we conjecture that for broker-intermediated trades information frictions should be less important to OTC discount than for bilateral trades. Since, consequently, dealers that provide liquidity via brokers need to insure themselves against being adversely selected, transaction costs are higher and spreads wider than on the exchange. We therefore expect a lower OTC discount for broker trades than for bilateral OTC trades.

C. Predictions for Venue Choice

In this section we deduce expectations for dealers' venue choice decisions from theoretical considerations related to market and information frictions. We focus first on the venue choice of trading on an exchange vs. over-the-counter. In a second step we discuss predictions for broker trades.

Market frictions. As outlined above, dealers with greater bargaining power are expected to receive more favorable transaction prices in OTC negotiations. The probability of trading OTC should thus increase with bargaining power, as dealers are able to generate more profit from exploiting their bargaining position relative to prices on the exchange that are unaffected by bargaining.

As before, we relate bargaining power to the availability of outside options. These are reduced for large trades (when trading on the exchange is less viable because of the increased costs of trading thereon) and when volatility is high (so that continued search implies higher execution risks). We therefore expect exchange trading to be less likely for larger trades and more likely when volatility is high.

We are aware that venue choice depends on the expected transactions cost. In the venue choice analysis, we thus use a measure of *Expected OTC discount* based on the dealer's recent trading activity. A higher expected discount in the OTC segment reflects more bargaining power, and should therefore lower the probability of exchange trading.[25] We further take into account whether a trade is with or against the overall order flow in the market. Trading with the flow deteriorates the relative bargaining position, and therefore we expect exchange trading to be more likely for such transactions. As before, we use *Aggregate order flow* to capture the net order flow of OTC trades in all Bunds

[24] E.g. the AFME European Primary Dealers Handbook (part 17.6, available at `https://www.afme.eu/en/reports/publications/european-primary-dealers-handbook-q3-2017/`) describes the services of the interdealer broker BGC Partners as: "All trading is conducted anonymously, with no voice brokerage desk access to electronic counterparty names."

[25] The observed OTC discount is similarly affected by the endogenous venue choice of dealers. We account for this selection bias in robustness checks described in the Appendix.

prior to the trade on that day and *Order book imbalance* for the direction indicated by imbalances in the best three levels of the order book.

Dealers unwinding a large inventory may need to do so quickly and therefore make use of the immediacy provided by the exchange. Thus, we expect a negative relation of the *Inventory* variable (unwinding trades have negative sign) with the probability of trading on the exchange.

Lastly, we also consider dealer characteristics. Li and Schürhoff (2019) identify central dealers with higher bargaining power, implying that they should be more likely to trade over-the-counter. As we are unable to observe the full network structure, and given that dealer-fixed effects are problematic in a probit setup, we instead consider the variable *Dealer volume*, the overall volume traded by a dealer, and associate dealers with larger volume with higher centrality in the network.

Information frictions. In theories featuring adverse selection (Seppi, 1990; Lee and Wang, 2017), counterparties in the OTC market are partially able to infer the information content of a trade. Hence, informed traders will receive worse prices and prefer the exchange. We therefore expect trades with higher price impact and trades from order splitting strategies to be more likely executed on the exchange.

On the other hand, Babus and Kondor (2018) argue that central dealers are better informed through the order flow they receive and would thus avoid trading bilaterally with other dealers in order to protect their private information.[26] If such an information friction were to dominate the search friction, we would therefore expect dealers with a larger overall volume to be less likely to trade bilaterally.

Theoretical guidance on dealers' choice whether to trade via a broker rather than bilaterally is limited. An exception is Bruche and Kuong (2019) who predict that the share of broker trades should increase for larger trades. This aligns with conversations with market participants which suggest that the probability of a trade being routed via a broker should be higher for larger trades (see also Holland, 2001). Given that these large dealers are hardly able to satisfy all their trading needs via the exchange and in client interactions, this would imply that larger dealers (here those with a higher overall *Dealer volume*) are more likely to trade with each other via brokers that provide opacity, in line with Babus and Kondor (2018).

V. Drivers of OTC Discount

In this section we document our empirical results on how market and information frictions affect transaction costs in the Bund market. We first consider the determinants of

[26] An information acquisition channel as in Naik, Neuberger, and Viswanathan (1999) might incentivize more informed trades to be transacted bilaterally due to higher discounts from counterparties eager to receive information from trading interactions.

OTC discount for bilateral and broker-facilitated trades. We then analyze the differences between OTC discount of bilateral and broker-facilitated trades and study their average price impact.

A. The Importance of Information and Market Frictions

To test the predictions from Section IV.B, we jointly study the importance of variables measuring market and information frictions for OTC discount in the interdealer Bund market. We estimate the following equation at the level of individual trades:

$$OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n, \tag{2}$$

where the dependent variable is the OTC discount of trade n, defined in Equation (1) and given in units of percentage points, v_n is a vector of trade, dealer and bond characteristics, and Δ_b and Δ_i are bond- and (initiating) dealer-fixed effects, respectively. v_n includes proxy variables for market and information frictions, as well as a set of control variables. The components of v_n vary at the trade, day, intraday time, initiator and/or initiator-counterparty level as detailed in Table III. The control variables account for exchange market liquidity (MTS bid-ask spread and depth of the limit order book on the side of the trade), bond age, on-the-run status, cheapest-to-deliver status, end-of-quarter or end-of-year effects, issuance days, whether trade size was a "round" amount, and for whether a trade took place on a platform other than MTS. We estimate Equation (2) using ordinary least squares with standard errors clustered at the day, bond and dealer level.

Table V presents the results of the estimation of Equation (2). Specifications (1) and (2) report the estimations for bilaterally negotiated OTC trades between MTS dealers (corresponding to row "D2D via bilateral OTC" in Table II) and specifications (3) and (4) for interdealer trades via brokers (corresponding to row "D2D via broker (D2B)" in Table II).[27] The minimum trade size is 2 million EUR in all specifications, and in specifications (2) and (4) we also impose an upper limit on nominal trade size of 25 million EUR.[28]

Market frictions. We first consider the role of market frictions relating to dealers' bargaining power and inventory in driving OTC discount.

In line with the theoretical predictions, we find that doubling the trade size (which reduces the feasibility of the exchange MTS as an outside option) reduces the OTC

[27] We include both broker trades where we observe the dealer-to-broker and the broker-to-dealer leg of the trade. For the latter subsample, some variables are imperfectly estimated. We conducted extensive robustness checks to ensure that our results hold, both by excluding the affected variables and removing those trades from the sample.

[28] 25 million EUR corresponds to the 99.4th percentile of trade size on MTS. Trades larger than this are unlikely to be executed on MTS (in a single transaction) and excluding them constitutes a robustness check for our results.

discount of a bilateral trade by 1.20 percentage points.[29] On the 10% most volatile days (when the outside option of continued search is less feasible) OTC discount is 10.1 and 11.7 percentage points lower for bilateral and broker OTC trades. This effect is significant and sizeable compared to an average OTC discount of 48.0 (25.4) percentage points for bilateral (broker) trades, corresponding to more than one (two) fifths of average OTC discount and thus highlighting the relevance of immediacy.

Also in line with our hypotheses, trading in the same direction as the overall market lowers OTC discount significantly. The estimates imply that when a net 1 billion EUR of Bunds have been bought on the same day prior to the trade, OTC discount for another buy trade is, on average, 2.9 - 3.7 percentage points lower. The imbalance of the order book yields only a slightly significant effect in specification (1).

Our inventory variable is not significant for either segment of the OTC market. Indeed, conversations with market participants reveal that the availability of the futures contract as a hedging instrument alleviates potential inventory concerns. We thus conclude that inventory frictions do not play an important role in the interdealer Bund market, in contrast to the evidence provided, e.g., by Friewald and Nagler (2018) for the corporate bond market.[30]

Beyond the trade-specific measures of bargaining power analyzed above, we can also assess the individual bargaining power of different dealer banks via the dealer fixed effects included in the estimation. Since we control for a series of other drivers, including inventory, informedness and market liquidity, we associate dealers with a higher fixed effect to more bargaining power. For confidentiality reasons we cannot report the individual dealer fixed effects. Their standard deviation across dealers is about 14 percentage points of the MTS half-spread – more than one quarter of average OTC discount – in specification (1), and similarly so for the other specifications. This suggests that dealer-specific bargaining power plays a quantitatively important role for OTC discount, over and above the proxies included in our regressions.

In sum, along the three dimensions of bargaining power considered, we find consistent evidence that search frictions determine transaction costs, in line with search-based theories of OTC markets (Duffie, Gârleanu, and Pedersen, 2005, 2007). Dealers with

[29]To arrive at these numbers, we multiply the estimation coefficient of logarithmic trade size with $\log 2 \approx 0.69$. Since in specification (2) the trade size is capped at 25 million EUR, it is not surprising that the effect is not present.

[30]As dealers use the repo market to manage their inventory, one might expect that the repo specialness of a security has an effect on its OTC discount. Adding specialness as a control, however, we did not find significant coefficients. That said, specialness is likely well captured by the end-of-year and end-of-quarter dummies in our regressions which we find to be statistically significant.

more bargaining power on average have lower transactions costs and receive higher OTC discount. This is true for both bilateral OTC trades and trades via interdealer brokers.[31]

Information frictions. Next, we consider the role of (perceived) informedness of trades. Both our proxies of price impact after 15 minutes and order splitting are negative and significant for bilateral OTC trades. A one basis point higher price impact corresponds to a 0.25 - 0.29 percentage points lower OTC discount, and trades that are part of an order splitting strategy receive a 3.5 percentage points lower discount. This is in line with the predictions from information-based models and indicates that dealers are price discriminating against each other when trading bilaterally. For interdealer trades via brokers the estimation coefficients are smaller and insignificant. We interpret this as evidence that dealers trading via a broker are less able to infer the informedness of their counterparty.[32]

Our results are robust with respect to several important dimensions, and we present the corresponding robustness analyses in the Appendix. First, we consider alternative definitions of OTC discount, where a) we include the effect of larger trades walking up the limit order book and consuming liquidity from deeper levels of the limit order book, and b) we normalize OTC discount by price instead of transaction cost. Second, we control for a potential selection bias from venue choice. Third, we consider shorter sample periods that exclude the European debt crisis and the purchases of Bunds by the Eurosystem as part of its Public Sector Purchase Programme. All results are quantitatively and qualitatively in line with those presented here.

B. Interdealer Brokerage

In the previous subsection we have found that market frictions, and in particular bargaining power, are important drivers of OTC discount in both bilateral and broker-facilitated OTC transactions. Information frictions, on the other hand, drive OTC discount only in bilateral trades, but do not play a significant role for broker trades, in line with our discussion in Section IV.B.2 that brokers provide a layer of opacity that makes it difficult to price discriminate based on the perceived informedness of order flow. In order to better understand the role and functioning of interdealer brokers we carry out two additional analyses. First, we single out the difference in transaction cost and OTC discount between bilateral and broker trades by creating a sample of trades that differ primarily in their

[31] We also control for market liquidity on the exchange using the MTS half-spread and depth at the best level of the MTS order book (on the respective side of the trade). Across all specifications MTS half-spread is a significant driver of OTC discount: the larger the bid-ask spread, the higher is the average OTC discount. This implies that deteriorations of liquidity conditions on the exchange are only partially passed on to the OTC segment. A deeper book correlates with a higher OTC discount on average; however this effect is significant only in specification (4).

[32] We have verified that our results are robust when considering similar horizons for price impact, such as 5 or 30 minutes, and when considering only the last child order in cases of order splitting.

trading mechanism (bilateral vs. via broker) and are otherwise comparable. Second, we consider the average price impact of bilateral and broker trades to investigate the informedness of broker order flow.

Matched Sample Analyis. To compare the transaction costs of bilateral and broker trades, we construct a sample of trades that differ in the trading mechanism but not across other dimensions. Specifically, we create a matched sample that pairs bilaterally negotiated trades with similar broker transactions using "nearest neighbor" propensity score matching. The variables used in the matching procedure are the MTS bid-ask spread, (logarithmic) trade size, the date, bond identifier, the identity of the initiating dealer, the direction of the trade, volatility, and dummy variables for whether a bond was issued or reopened on the same day, its status as cheapest-to-deliver bond in the current futures contract, on-the-run status and end-of-quarter and end-of-year effects. We enforce strict matching on the bond and dealer dimension, that is, we allow only for perfect matches of trades from the same dealer in the same security on the same day. We impose minimum closeness criteria for the other matching characteristics. Furthermore, we only consider trades where the initiating party is obliged to report to our transactions database, i.e. where we observe the dealers' full trading activity.

Table VI shows the results of estimating Equation (2) using the matched sample described above, where additionally we introduce a dummy variable *Trade via broker*, which takes the value 1 for broker trades and 0 for bilaterally negotiated OTC trades. The main result is that the OTC discount of broker trades is $15.6 - 17.8$ percentage points lower than for comparable bilateral trades. This difference is sizeable, given that the average OTC discount of bilateral interdealer trades reported in Table II is 48 percentage points, i.e. corresponding to roughly one third of the discount.[33]

This finding is consistent with both the information and search theories. On the one hand, broker trades might have a lower discount and higher transaction costs since they provide a faster and/or more efficient intermediation of trading interests. On the other hand, since brokers provide anonymity to traders, liquidity providers may insure themselves against being adversely selected by quoting wider spreads.

Price Impact Analyis. To further understand the role of interdealer brokers and of price discovery across the different segments of the Bund market in general, we study the average price reaction to trades. As a proxy for price impact of trades in the exchange and OTC segments we compute the average price response of MTS mid-quotes to trades

[33]The estimation coefficient is in line with the average difference in OTC discount between bilateral and broker trades of 22.7 percentage points as reported in Table II, but controls for trade characteristics. The effect we find is also considerably larger than broker fees, which are of the order of 0.15 basis points, see the rate card for European government bonds of the interdealer broker Tradition, available at `https://www.tradition.co.uk/about-us/compliance/documents/other.aspx`.

in each segment. Formally, we define response as

$$R_h^s = \mathbb{E}\left[\left(X_{t+h-\varepsilon} - X_{t-\varepsilon}\right)\epsilon_t^s | \mathbb{1}_{\text{Trade}_t^s}\right], \quad (3)$$

where X_t is the log MTS mid-price of bond i at time t and ϵ_t^s is the order sign of the trade ($+1$ for buys, -1 for sells) which occurred at time t in market segment $s \in \{\text{MTS}, \text{bilateral OTC}, \text{broker}\}$. That is R_h^s represents the logarithmic return over the horizon h, conditioning on a trade in market segment s. Differently from above, where we considered the price impact of *individual* trades, here we focus on the *average* price reaction to *all* trades in a market segment.

Figure 3 shows the evolution of the MTS mid-price in response to exchange, bilateral and broker OTC trades over a horizon of up to one hour.[34] The average response to exchange trades is largest. Prices jump instantaneously, reach their maximum of about 1.3 basis points above the previous trade price after about ten minutes, and move sideways afterwards. The average response to bilateral OTC trades is considerably smaller than for exchange trades. It is 0.24 basis points in the minute after the trade and then slowly increases to about 0.7 basis points one hour after the trade. Broker trades have essentially no price impact.[35]

The large and immediate response on the exchange is likely due to two factors. First, a larger trade might cause a mechanical impact on the mid-price when depleting the best level(s) of the limit order book. Second, any exchange trade can be observed by other market participants who may adjust their quotes accordingly.[36] Bilateral OTC trades are instead observed only by the two parties involved. Therefore, it is unsurprising that information from the trade is disseminated much more slowly across the market. The smaller response suggests a lower information content of bilateral OTC trades, in line with information-based models of hybrid markets.

Strikingly, the average response to broker trades is essentially zero and thus much lower than for exchange and bilateral OTC trading. This suggests that broker trades are, on average, uninformed, supporting the search but not the information channel discussed in Section IV.B.2.

This result could be reconciled by considering the informational difference between bilateral and broker trades as due to the desire of dealers to protect themselves against price revision risk (Naik, Neuberger, and Viswanathan, 1999) and predation risk due to

[34]For ease of exposition, Figure 3 shows the reponse of 10-year Bunds to trades of at least 2 million EUR. Results are similar when considering wider sets of trades or the matched set of trades described above.

[35]Accounting for a (linear) dependence on trade size (i.e. calculating response per million EUR traded) yields an even more pronounced separation of response across segments, since average trade sizes increase from exchange to bilateral OTC to broker trades, see Table I.

[36]Despite the low number of trades on MTS, limit orders thereon follow high-frequency dynamics in line with algorithmic trading; see Schneider, Lillo, and Pelizzon (2018).

frontrunning (Harris, 1997) or predatory trading by other dealers (Brunnermeier and Pedersen, 2005), instead of adverse selection due to differential private information. By providing opacity about the identities of involved counterparties as well as about the occurrence of trades, interdealer brokers alleviate the above issues. Crucially, the lack of counterparty information relates to a virtual absence of price impact, and dealers are willing to forego a share of OTC discount with respect to bilateral trades in order to protect their identity.

Our results highlight some similarities between the interdealer broker segment in the Bund market and size-discovery mechanisms such as the "work up" in the U.S. Treasury market (Duffie and Zhu, 2017; Fleming and Nguyen, 2018). Consistent with our findings for broker trades Fleming and Nguyen (2018) show that the order flow from the work up causes less price impact than regular trades on the central limit order book. In our setting interdealer brokers operate independently from the exchange platform, and our findings suggest that the price impact of broker trades is even lower than the one due to the work up order flow. Interestingly, Antill and Duffie (2019) present a mechanism that allows for size-discovery sessions that efficiently reallocate assets across traders without price impact.

VI. Drivers of Venue Choice

Having established that transaction costs are structurally different in OTC trades and on the exchange, we now turn our focus to the factors that lead dealers to trade via either of these mechanisms.[37] We model this choice as a sequential decision: first we consider the choice between trading on the exchange or OTC. If a trade is executed OTC, we study the decision between trading bilaterally or via a broker.[38]

A. Exchange versus OTC

In order to study the dealers' decision whether to trade on the interdealer exchange MTS or over-the-counter, we estimate a probit model where the dependent variable MTS equals one for MTS trades and zero otherwise. Formally, we estimate

$$Pr(MTS_n) = f(\omega_n) \tag{4}$$

[37] We do not observe dealers' decision whether to trade or not. Especially in the OTC market, a trader might be able to find a counterparty to a transaction only at a cost that outweighs the expected benefits of the trade. For example, Hendershott and Madhavan (2015) report that, on average, only $51.0 - 73.4\%$ of electronic auctions (corresponding to multi-dealer requests-for-quote) lead to trades and $8.2 - 14.7\%$ of such auctions do not receive a quote from a dealer.

[38] We consider the decision whether to trade on the exchange first, since execution is certain and immediate. We have ensured robustness of our results using combined samples and different sequencing.

at the level of individual trades indexed by n, where ω_n is a vector of independent variables including security and trade characteristics. The vector of trade and bond characteristics, ω_n, is similar to the one specified in the previous section, v_n, where instead of dealer-fixed effects we use the variable *Dealer volume* to capture a given dealer's overall trading volume, and instead of bond-fixed effects we use a set of bond characteristics as controls. The control variables account for market liquidity (MTS bid-ask spread and depth of the limit order book on the side of the trade), logarithmic amount outstanding, bond age (in percent), the coupon rate (in percent), on-the-run status, cheapest-to-deliver status, end-of-quarter or end-of-year effects, issuance days, whether trade size was a "round" amount, and dummy variables for whether a bond has a maturity of issuance of 2, 5 or 30 years.

Table VII shows the marginal effects of the probit estimation, with standard errors clustered at the dealer level. Our sample consists only of trades that are able to take place in either section of the market, i.e. trades between MTS dealers with a minimum size of 2 million EUR that took place during MTS trading hours.[39] We consider two different samples: in specification (1) there is only the lower bound of 2 million EUR on trade size, in specification (2) an upper limit to trade size of 25 million EUR of nominal amount is additionally present.

Market frictions. We first consider the effect of market frictions on dealer venue choice. Larger trades are less likely to be routed to the exchange since MTS transaction costs increase with trade size. Doubling the trade size makes trading on the exchange 6.5 - 7.2 percentage points less likely. The dummy variable for volatile days is highly significant and implies that on such days trading on the exchange is 6.4 - 7.8 percentage points more likely, in line with the notion that the outside option of continued search is less feasible. For trades with a higher expected discount, the probability of trading on MTS is lower; that is, traders with a higher expected bargaining power are more likely to trade over-the-counter than on the exchange. The proxy for aggregate order flow is insignificant throughout. Order book imbalance is of the opposite sign than what we expected, but very small and significant only when including also very large trades in estimation (1) but not in (2). We find no evidence that either market segment is preferred for inventory management, in accordance with the insight that inventory concerns are alleviated through the futures market. Furthermore, we find no significant effect with respect to dealer volume, i.e. larger dealers are, on average, not more likely to trade on the exchange or OTC.

Information frictions. Both our measures of trade informedness are significant and point in the same direction: better informed dealers are more likely to trade on the

[39] We consider only trades where the initiating dealer is reporting to our transactions dataset, i.e. we observe the full trading activity of dealers in question. We also exclude trades for which the bid-ask spread on MTS was prohibitively high, setting the threshold at 100 basis points, which corresponds to the 99%-percentile across all bonds and the 95%-percentile for 30-year Bunds, the least liquid bonds in our sample.

exchange. A one basis point higher return implies an increased probability to trade on MTS by a little above 0.3 percentage points in the two specifications. Transactions that have been split in smaller trades are on average between 3.6 percent and 4.5 percentage points more likely to trade on MTS. This supports the prediction of information-based models for hybrid markets that informed traders prefer the exchange.

Market liquidity and other control variables. Market liquidity also plays an important role for venue choice. The MTS bid-ask spread is a highly significant driver; a one basis point increase in the half-spread makes it 1.2 - 1.4 percentage points less likely that a trade is transacted on MTS. Cheapest-to-deliver bonds are $4.8-5.5$ percentage points less likely to be traded on the exchange, and 30-year Bunds, which typically quote at considerably higher bid-ask spreads, are $15.0-17.3$ percentage points more likely to be traded on the exchange. Both findings confirm the prediction of Lee and Wang (2017) that assets with wider bid-ask spreads on exchanges should be traded more often on exchanges.

B. Broker versus Bilateral OTC

Given that a trade was not executed on the exchange but OTC, we now turn to the decision whether to trade via a broker or through bilateral OTC negotiations. Formally, we estimate

$$Pr(Broker_n) = g(\omega_n) \tag{5}$$

at the level of individual trades indexed by n, where as above ω_n is a vector of independent variables that should be relevant for the venue choice decision. The dependent variable *Broker* equals one for trades via a broker and zero otherwise (i.e. bilaterally negotiated OTC transactions).

Table VIII shows the marginal effects of the probit estimation, with standard errors clustered at the dealer level. Our sample consists of interdealer OTC trades with a minimum size of 2 million EUR that took place during MTS trading hours. As above, we restrict the sample to those trades where we observe the initiating leg of a trade in order to not introduce a bias from unobserved characteristics in broker trades. An upper limit on trade size of 25 million EUR is additionally present in specification (2).

Market frictions. Table VIII confirms our earlier observations from Table I that larger trades tend to be executed via brokers. A doubling of trade size makes an otherwise equal trade 9.1 percentage points more likely to be carried out via a broker than bilaterally. We do not find significance for the dummy variable for very volatile days, suggesting that immediacy concerns play no role for the decision whether to trade bilaterally or via a broker. Also, neither the expected OTC discount nor our order flow variables are significant.

The coefficient for dealer volume is significant and positive. That is, large dealers are more likely to trade via brokers than bilaterally. Assuming that dealers with larger volume are more central, our findings are in line with the notion that central dealers prefer to preserve their informational advantages about order flows or inventories and thus avoid trading directly with each other (Holland, 2001; Babus and Kondor, 2018).

Information frictions. None of our proxy variables for informedness is a significant driver of the choice whether to trade via a broker or bilaterally. We thus find no evidence that broker trades are, on average, more informed than bilateral OTC trades, despite the anonymity provided by the broker.

In summary, our findings imply a "pecking order" of trade size. As trade size increases, the preference of venue shifts from the exchange to bilateral OTC negotiations to broker-facilitated trading. This is in line with the notion that brokers reduce search frictions and price revision risk for large trades, and especially so for central dealers. Furthermore, we show that the exchange, even though it attracts only a small share of overall interdealer trading activity, represents a valuable outside option when dealers require immediacy or for trades in less liquid bonds.

VII. Conclusion

In an environment where academics and regulators increasingly call for a shift from traditional over-the-counter market structures towards electronic platforms and greater transparency, an in-depth understanding of the drivers and motivations behind the pricing in different market segments and venue choice is ever more important. This is especially true in light of the observed persistence of opaque market structures, which appears surprising given the parallel existence of alternative electronic trading venues that allow for fast and more transparent pricing. Moreover, the increasingly important role that safe assets play for regulatory requirements, policy implementation, and collateral provision call for an analysis of the pricing and liquidity of such assets in different markets.

In this paper we contribute to this understanding along several dimensions. Using a unique regulatory dataset of securities transactions, we study the price differences between market segments and their drivers in dealer-to-dealer transactions in the German Bund market. Our main finding is that the large majority of OTC trades execute well inside the spread quoted on the interdealer limit order book, implying a sizable discount for most OTC transactions. We show that the magnitude of OTC discount in bilateral trades is driven by both market and information frictions, reflecting the bargaining position of dealers and their perceived informedness. Exploring venue choice, we document that dealers are more likely to execute a trade on the exchange when the required immediacy is high, and for less liquid bonds, i.e. the exchange acts as an outside option and as a potential provider of "liquidity-of-last-resort".

However, we also find that the most active segment, with more than three quarters of interdealer trading volume, is interdealer brokers. These broker trades are on average larger than other trades, receive lower discounts than comparable bilateral trades, and, strikingly, feature no discernible price impact. We link these features to the opacity provided by brokers, and the dealers' desire to reduce their price revision risk.

Our findings suggest that dealers use the three venues of the hybrid interdealer market for different needs which a single venue might not be able to satisfy. These aspects ought to be considered in the design and regulation of fixed-income trading. While our empirical analysis cannot answer the important question which market structure is socially preferable, our results highlight that theories which address this question may have to consider both information and market frictions.

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Figures

Figure 1. Trade Sign and OTC Discount: We classify OTC trades above (below) the quoted mid-price on MTS as buyer- (seller-) initiated. *OTC discount* is the price difference between the quoted best bid (ask) price on MTS for a buyer- (seller-) initiated trade and the actually observed price of the trade, symmetrized for buyer- and seller-initiated trades. By this definition, a positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. We identify an *OTC premium* where OTC discount is negative, i.e. when trading on MTS would have been cheaper. Trades at the mid-price have 100% OTC discount, whereas buys at the MTS ask price and sells at the MTS bid price have 0% OTC discount, i.e. the OTC trade presented no price improvement over MTS.

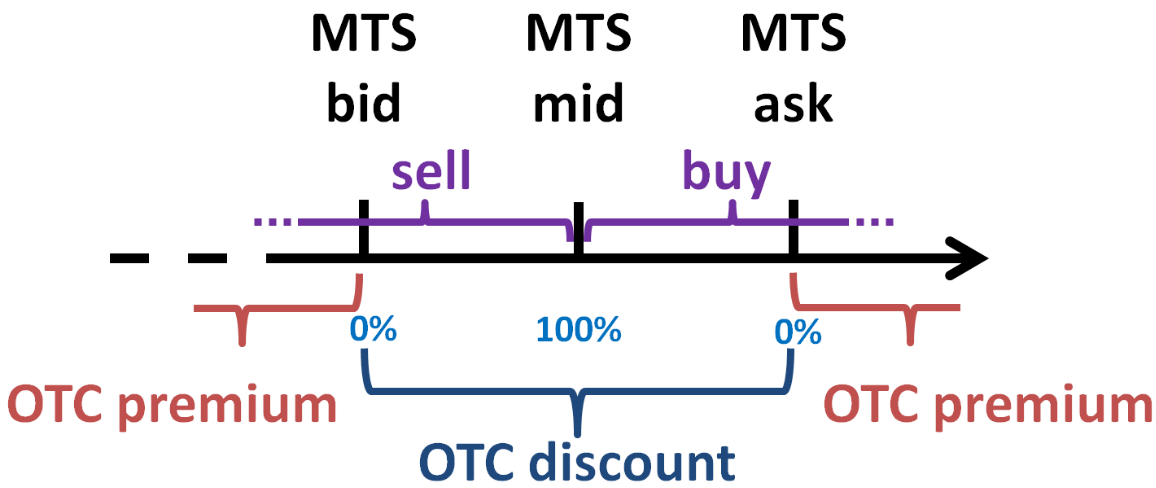
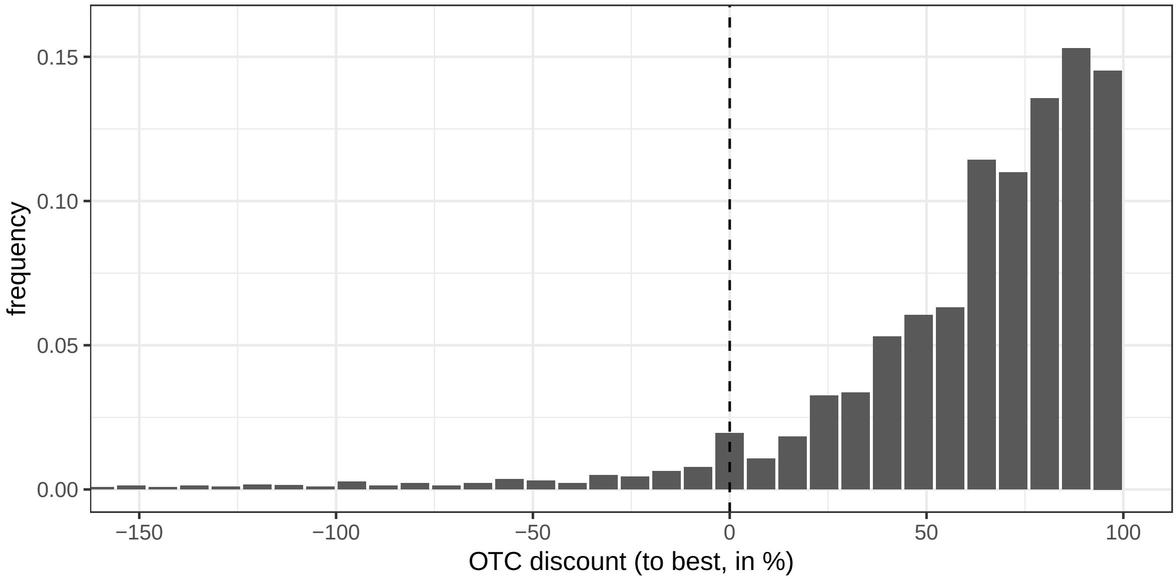
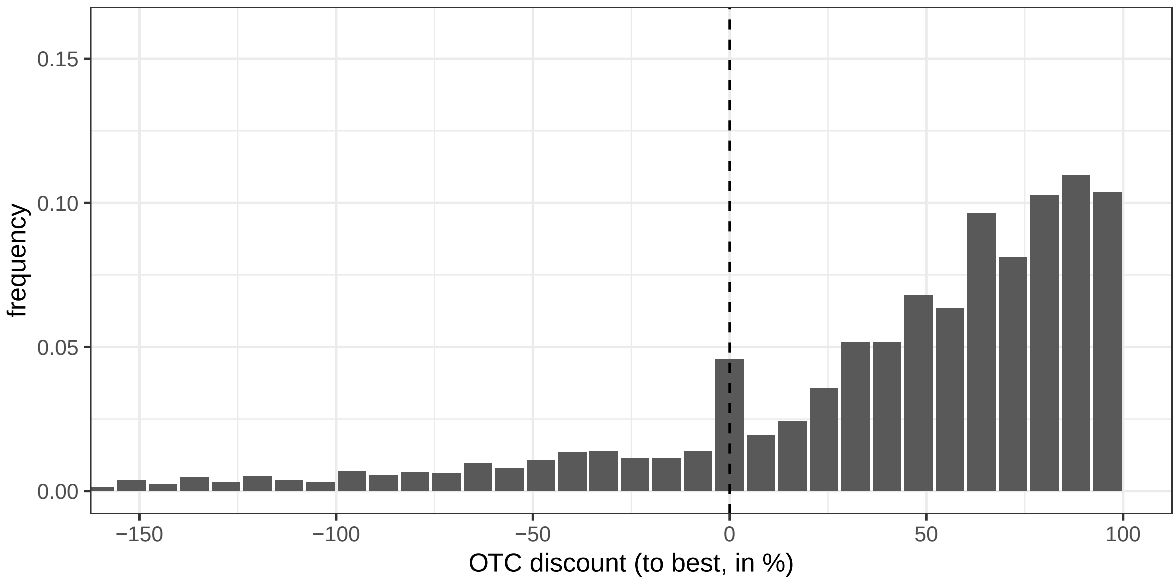


Figure 2. Histogram of OTC Discount: *OTC discount*, defined in Equation (1) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. It is given in units of %. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. OTC discount is bounded from above to be at most 100%. The Figure shows the distribution of OTC discount based on interdealer trades of nominal size of at least 2 million EUR. Panel (a) refers to bilateral OTC trades and Panel (b) to trades via a broker. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

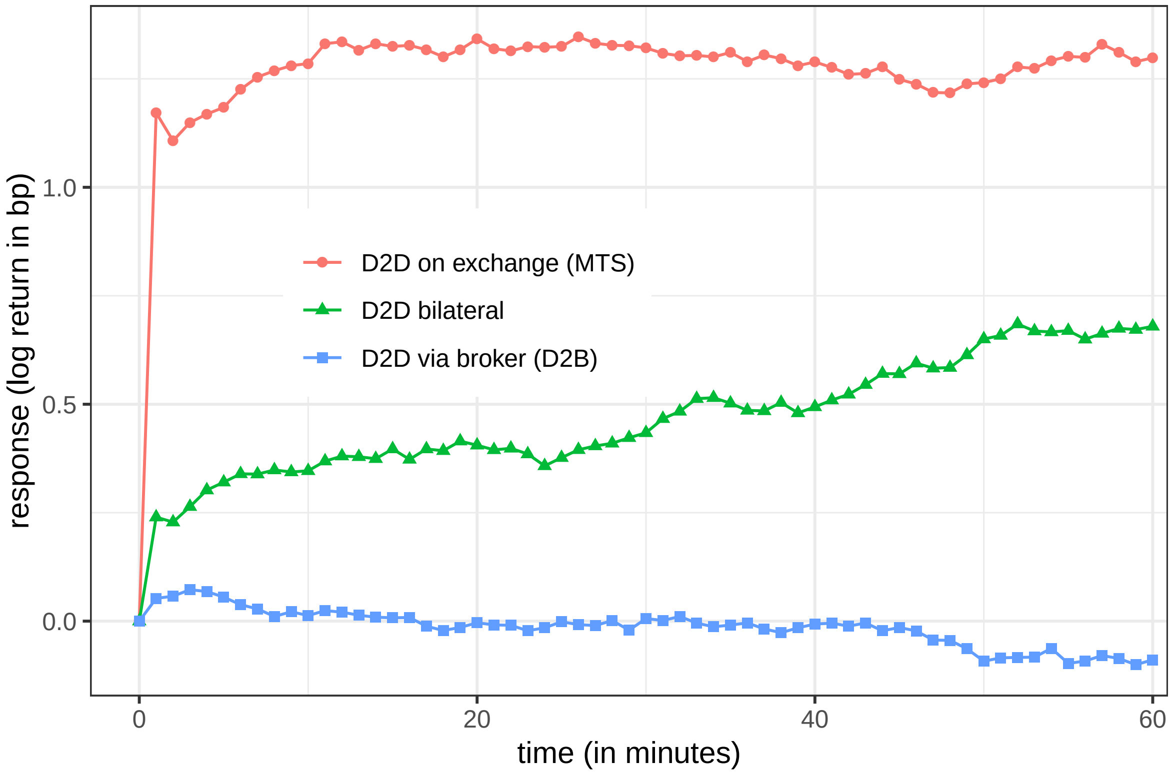


(a) Interdealer trades via bilateral OTC.



(b) Interdealer trades via broker.

Figure 3. Price Impact across Segments: Response function to trades in the exchange and OTC segments. The response function R_h^s is defined as $R_h^s = \mathbb{E}\left[(X_{t+h-\varepsilon} - X_{t-\varepsilon})\,\epsilon_t^s | \mathbb{1}_{\text{Trade}_t^s}\right]$, where X_t is the log MTS mid-price of bond i at time t and ϵ_t^s is the order sign of the trade (+1 for buys, −1 for sells) which occurred at time t in market segment $s \in \{\text{MTS}, \text{bilateral OTC}, \text{broker}\}$. R_h^s thus represents the logarithmic return over horizon h, conditioning on a trade in market segment s. The figure shows the response of 10-year Bunds to trades of at least 2 million EUR. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.



Tables

Table I. Trading Activity by Subsamples: This table provides an overview of trading activity for the full sample of observed trades and the subsamples used in our analysis. *Full sample* refers to the cleaned and unfiltered sample. The subset *trade size* $\geq$ *2 million EUR* includes all trades with a nominal amount of at least 2 million EUR, the minimum trade size on the interdealer exchange MTS. This subset is further reduced to trades where *both initiator and counterparty are known*, i.e. identified by an anonymized ID. In row *D2D* we focus on the interdealer trades among the latter subset, and distinguish them into: *D2D via MTS*, i.e. trades via the interdealer exchange MTS, *D2D via bilateral OTC*, i.e. trades bilaterally negotiated between two dealers, and *D2D via broker (D2B)*, i.e. interdealer trades intermediated by an interdealer broker. Reported are the number of trades for each subsample, the aggregated trade volume over our full sample period, the volume share of overall interdealer volume, and summary statistics of trade size (in terms of notional amount). Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

	# trades	trade volume		trade size						
		sum (billion EUR)	share of D2D (%)	Mean	Std Dev	5 Pcl	25 Pcl (million EUR)	Median	75 Pcl	95 Pcl
full sample	503,264	3,395.39		6.75	19.46	0.00	0.10	1.00	5.00	30.00
trade size $\geq$ 2 million EUR	198,326	3,274.43		16.51	28.35	2.00	4.00	6.00	18.00	54.00
init. & counterp. ID known	103,619	1,524.40		14.71	23.95	2.00	4.00	5.00	15.00	50.00
D2D	25,955	479.49	100.00	18.47	24.19	2.00	3.40	10.00	25.00	63.00
D2D via MTS	2,428	17.72	3.70	7.30	6.31	2.00	5.00	5.00	10.00	11.00
D2D via bilateral OTC	8,328	90.19	18.81	10.83	18.78	2.00	2.90	5.00	10.00	45.76
D2D via broker (D2B)	15,199	371.57	77.49	24.45	26.68	2.00	4.60	15.02	34.00	76.32

Table II. Descriptive Statistics of OTC Discount: *OTC discount*, defined in Equation (1) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. It is given in units of %. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. OTC discount is bounded from above to be, at most, 100%. Reported are summary statistics of OTC discount for the subsets defined in Table I, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. The column p-value gives the p-value for a t-test of the mean being different from zero and *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount to best (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,018	30.16	268.71	-109.50	32.00	65.71	84.00	96.23	13.50	0.0000
trade size ≥ 2 million EUR	176,271	26.68	361.65	-120.00	28.57	63.64	83.33	96.00	14.36	0.0000
init. & counterp. ID known	101,143	28.33	358.05	-100.67	30.88	64.71	83.33	96.00	13.49	0.0000
D2D	23,525	33.38	119.15	-120.00	27.59	62.60	82.86	96.00	15.03	0.0000
D2D via bilateral OTC	8,328	48.03	138.86	-33.33	45.71	70.00	86.15	96.36	7.32	0.0000
D2D via broker (D2B)	15,197	25.35	105.97	-152.50	12.50	56.80	80.00	95.66	19.25	0.0000

Table III. Variable Definitions: Definitions and details for the explanatory and control variables used in the paper. The column variation indicates the dimensions along which the variable varies, where d, t, b, and i indicate day, intraday time (minute), bond, and trade initiator, respectively. n indicates that a variable varies from trade to trade even with all other dimensions equal.

Variable	Description	Source	Variation
OTC discount	See Section III and Equation (1).	transactions, MTS & own calculations	n
Trade size (log)	Logarithm of market value of trade, where market value is in EUR.	transactions	n
Volatility (dummy)	Equals one if intraday volatility for the bond and day is among the top 10 percentile. Intraday volatility is calculated for each bond and day as the square root of the variance of 5-minute returns in MTS mid-prices.	MTS & own calculations	d, b
Aggregate order flow	Imbalance of the aggregate order flow (including dealer and customer trades) in all active bonds in our sample on the same day up to the time of the trade n. Signed for the direction of the trade n and given in billion EUR of nominal amount. E.g. a buy trade in a market situation with overall buying pressure has positive sign.	transactions & own calculations	n
Order book imbalance	Imbalance between volume of limit orders on the best three levels on both sides of the MTS limit order book at the time of trade n. Signed for the direction of the trade n and given in million EUR of nominal amount. E.g. a buy trade happening when there is less depth on the ask side has positive sign.	transactions, MTS & own calculations	n
Inventory	Net imbalance of the initiating trader with respect to the trade direction during the same day in the same bond up to the moment of the trade, normalized by the average daily volume of trading of the same dealer in the same bond.	transactions & own calculations	n
Price impact	Log return of the MTS mid-price of the traded bond 15 minutes after the trade with respect to the full minute before the trade. Signed for the direction of the trade n and given in basis points.	transactions, MTS & own calculations	d, t, b
Order splitting (dummy)	Equals one if a dealer trades the same bond more than once on the same trading day and in the same direction.	transactions & own calculations	d, b, i
MTS half-spread	Half bid-ask spread on MTS in the minute preceding the trade, in basis points.	MTS	d, t, b
Depth at MTS best	Volume available at the best level of the MTS order book on the side of the trade (i.e. ask/bid side for buy/sell) in million EUR.	MTS	d, t, b

Table III continued on next page.

Table III continued from previous page.

Variable	Description	Source	Variation
Trade via broker (dummy)	Equals one for trades via an interdealer broker and zero otherwise.	transactions	n
Expected OTC discount	Predicted OTC discount in percentage points of hypothetical MTS trade cost. Calculated as the OTC discount of the previous trade from the same dealer in the same bond or, where missing, (in order) as avg. OTC discount of the same dealer in the last 3 trades in this bond, avg. OTC discount by all traders in the last 30 days in the same bond, avg. OTC discount by the same dealer in all bonds in the last 30 days, avg. OTC discount by all dealers in all bonds in the last 30 days	own calculations	d, t, b, i
Round trade size (dummy)	Equals one if nominal trade size is a multiple of 5 million EUR and zero otherwise.	transactions	n
Dealer volume	Overall trade volume of the dealer. Nominal amount in trillion EUR.	transactions	i
Issuance day (dummy)	Equals one on the day of a primary auction for the bond auctioned and the bond going off-the-run in the case of a new issuance, and equals zero otherwise.	DFA	d, b
Cheapest-to-deliver (dummy)	Equals one if the bond is the cheapest to deliver for its respective futures contract and zero otherwise.	Bloomberg	d, b
Other platform (dummy)	Equals one if the trade took place neither OTC nor on MTS, i.e. on another trading venue or platform other than MTS.	transactions	n
Amount outstanding (log)	Logarithm of the outstanding amount of a given bond in EUR.	DFA & own calculations	d, b
Bond age	Time since the bond's first issuance divided by its maturity, in %.	DFA & own calculations	d, b
Coupon rate	Bond's coupon rate in percentage points.	DFA	b
End-of-quarter (dummy)	Equals one in the last 3 trading days of each quarter and zero otherwise.	own calculations	d
End-of-year (dummy)	Equals one in the last 3 trading days of the year and zero otherwise.	own calculations	d
On-the-run (dummy)	Equals one for the most recently issued 2-, 5- and 10-year Bund.	own calculations	d, b
2-year Schaetze (dummy)	Equals one if the bond has an original maturity of 2 years (Schaetze) and zero otherwise.	DFA	b
5-year Bobl (dummy)	Equals one if the bond has an original maturity of 5 years (Bobl) and zero otherwise.	DFA	b
30-year Bund (dummy)	Equals one if the bond has an original maturity of 30 years and zero otherwise.	DFA	b

Table IV. Statistics of Explanatory Variables: Descriptive statistics of explanatory and control variables as defined in Table III. The sample consists of interdealer trades for a minimum trade size of 2 million EUR for the following samples (as defined in Table I): Panel A refers to all trades on the interdealer exchange MTS in our transactions data, Panel B to bilaterally negotiated OTC trades and Panel C to interdealer trades via a broker. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

Panel A: D2D via MTS

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Trade size (log)	15.66	0.62	14.55	15.43	15.60	16.13	16.35	2,428
Volatility (dummy)	0.11							2,428
Aggregate order flow (bn EUR)	-0.00	0.48	-0.77	-0.20	0.00	0.20	0.71	2,428
Order book imbalance (mn EUR)	-1.16	28.18	-32.32	-7.00	-0.00	10.00	27.00	2,428
Inventory (%)	-19.94	54.84	-105.85	-39.88	-11.90	4.27	45.07	2,428
Trade return (15min, in bp)	1.63	6.41	-3.35	-0.00	0.49	2.08	11.37	2,383
Order splitting (dummy)	0.37							2,428
MTS half-spread	3.43	6.62	0.25	0.90	1.50	3.00	15.00	2,428
Depth at MTS best (log)	15.90	0.81	14.51	15.42	16.12	16.12	17.47	2,428
Expected OTC discount	0.56	0.37	-0.22	0.40	0.67	0.84	0.96	2,425
Round trade size (dummy)	0.70							2,428
Dealer volume (tn EUR)	0.30	0.30	0.00	0.01	0.11	0.65	0.67	2,428
Issuance day (dummy)	0.05							2,428
Cheapest-to-deliver (dummy)	0.05							2,428
Amount outstanding (log)	23.51	0.38	22.52	23.43	23.56	23.72	23.90	2,428
Bond age (%)	46.18	32.10	1.16	15.18	43.64	77.88	93.89	2,428
Coupon rate (%)	2.23	1.74	0.00	0.50	2.00	3.75	5.00	2,428
End-of-quarter (dummy)	0.05							2,428
End-of-year (dummy)	0.01							2,428
Recent on-the-run (dummy)	0.11							2,428
2-year Schaetze (dummy)	0.20							2,428
5-year Bobl (dummy)	0.21							2,428
30-year Bund (dummy)	0.13							2,428

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Panel B: D2D bilateral OTC

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Trade size (log)	15.68	0.94	14.56	14.94	15.46	16.18	17.68	8,328
Volatility (dummy)	0.06							8,328
Aggregate order flow (bn EUR)	0.02	0.52	-0.78	-0.17	0.02	0.22	0.82	8,328
Order book imbalance (mn EUR)	1.56	14.70	-20.00	-5.00	0.00	10.00	20.50	8,328
Inventory (%)	-16.96	69.73	-126.39	-33.70	-6.89	9.00	59.01	8,328
Trade return (15min, in bp)	0.45	14.00	-4.97	-0.88	-0.00	1.33	6.02	8,067
Order splitting (dummy)	0.21							8,328
MTS half-spread	5.53	64.86	1.25	2.25	3.00	4.00	12.50	8,328
Depth at MTS best (log)	15.87	0.64	14.51	15.42	16.12	16.12	16.81	8,328
Expected OTC discount	0.59	0.35	-0.14	0.45	0.68	0.85	0.96	8,328
Round trade size (dummy)	0.31							8,328
Dealer volume (tn EUR)	0.26	0.27	0.00	0.02	0.11	0.42	0.67	8,328
Issuance day (dummy)	0.02							8,328
Cheapest-to-deliver (dummy)	0.07							8,328
Amount outstanding (log)	23.58	0.31	23.03	23.50	23.61	23.77	23.90	8,328
Bond age	36.54	27.95	1.57	9.50	33.49	56.12	88.86	8,328
Coupon rate	2.03	1.50	0.00	0.50	1.75	3.25	4.25	8,328
End-of-quarter (dummy)	0.05							8,328
End-of-year (dummy)	0.01							8,328
Recent on-the-run (dummy)	0.17							8,328
2-year Schaetze (dummy)	0.09							8,328
5-year Bobl (dummy)	0.24							8,328
30-year Bund (dummy)	0.05							8,328

Panel C: D2D via broker

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Trade size (log)	16.49	1.17	14.62	15.43	16.69	17.40	18.24	15,199
Volatility (dummy)	0.11							15,199
Aggregate order flow (bn EUR)	0.07	0.51	-0.70	-0.15	0.05	0.26	0.92	15,199
Order book imbalance (mn EUR)	1.06	14.60	-20.00	-5.00	0.00	10.00	20.00	15,199
Inventory (%)	-7.47	53.73	-88.20	-25.55	-3.59	13.21	64.10	15,199
Trade return (15min, in bp)	0.14	7.54	-6.55	-0.99	0.00	1.42	7.36	14,815
Order splitting (dummy)	0.32							15,199
MTS half-spread	6.25	22.73	1.00	2.00	3.00	4.50	25.00	15,199
Depth at MTS best (log)	15.88	0.64	14.51	15.42	16.12	16.12	16.81	15,199
Expected OTC discount	0.55	0.39	-0.28	0.39	0.67	0.84	0.96	7,687
Round trade size (dummy)	0.49							15,199
Dealer volume (tn EUR)	0.32	0.25	0.03	0.09	0.22	0.65	0.67	15,199
Issuance day (dummy)	0.06							15,199
Cheapest-to-deliver (dummy)	0.15							15,199
Amount outstanding (log)	23.50	0.38	22.33	23.40	23.61	23.72	23.90	15,199
Bond age	29.97	27.28	1.00	5.85	21.63	50.09	84.32	15,199
Coupon rate	1.93	1.59	0.00	0.50	1.75	3.25	4.75	15,199
End-of-quarter (dummy)	0.03							15,199
End-of-year (dummy)	0.00							15,199
Recent on-the-run (dummy)	0.20							15,199
2-year Schaetze (dummy)	0.12							15,199
5-year Bobl (dummy)	0.22							15,199
30-year Bund (dummy)	0.13							15,199

Table V. Drivers of OTC Discount: Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left-hand variable, *OTC discount*, defined in Equation (1) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral OTC trades between MTS dealers in specifications (1) and (2) and trades between MTS dealers and interdealer brokers in specifications (3) and (4). The minimum trade size is 2 million EUR in all specifications, and in specifications (2) and (4) we further constrain the sample to trades for at most 25 million EUR. Control variables not shown are bond age, on-the-run status, cheapest-to-deliver status, end-of-quarter or end-of-year effects, a dummy controlling for issuance days, whether trade size was a "round" amount, and for whether a trade took place on a platform other than MTS. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at daily time, bond and dealer level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Market segment: Interdealer trades	bilateral OTC		via broker	
Trade size (million EUR):	≥ 2	$2-25$	≥ 2	$2-25$
	(1)	(2)	(3)	(4)
Trade size (log)	-1.7364*	-0.3999	-0.1927	-0.5054
	(-1.9161)	(-0.7418)	(-0.1762)	(-0.3107)
Volatility (dummy)	-11.6610***	-10.9370***	-10.4436**	-10.1386***
	(-4.5947)	(-3.8358)	(-2.9995)	(-3.0852)
Aggregate order flow (bn EUR)	-3.3201***	-2.8866***	-3.6918***	-3.5063***
	(-4.0324)	(-3.7866)	(-5.5676)	(-3.7372)
Order book imbalance (mn EUR)	-0.0522*	-0.0443	-0.0103	0.0070
	(-1.8712)	(-1.3785)	(-0.3460)	(0.1537)
Inventory	0.0069	-0.0021	-0.0002	0.0026
	(0.8010)	(-0.2686)	(-0.0123)	(0.1077)
Price impact (15min, in bp)	-0.2851**	-0.2496**	-0.0872	-0.0975
	(-2.0930)	(-2.3678)	(-0.8866)	(-1.0754)
Order splitting (dummy)	-3.5304**	-3.5220**	-0.8716	-0.1574
	(-2.3140)	(-2.4687)	(-1.1602)	(-0.1578)
MTS half-spread (bp)	2.1411***	2.0488***	1.5735***	1.4079***
	(6.6272)	(6.1653)	(5.2891)	(4.9061)
Depth at MTS best (log)	0.6263	0.9065	0.9596	1.4619*
	(0.9546)	(1.3496)	(1.2835)	(1.9944)
R^2	0.0994	0.0984	0.1348	0.1298
R^2_{adjusted}	0.0801	0.0780	0.1256	0.1164
R^2_{within}	0.0434	0.0386	0.0419	0.0400
N	7,825	7,295	13,586	9,266
Bond FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
Controls	yes	yes	yes	yes

Table VI. Drivers of OTC Discount: Matched sample of bilateral / broker OTC trades. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left-hand variable, *OTC discount*, defined in Equation (1) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral and broker OTC trades between MTS dealers. The trades are matched along the dimensions of trade size, MTS (half-)spread, date, bond (ISIN) and initiating dealer. Further details of the matching process are described in Section V.B. The minimum trade size is 2 million EUR in all specifications and in specification (2) we further constrain the sample to trades for at most 25 million EUR. Control variables not shown are bond age, on-the-run status, cheapest-to-deliver status, end-of-quarter or end-of-year effects, a dummy controlling for issuance days, and whether trade size was a "round" amount. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, dealer and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Trade size (million EUR):	≥ 2	$2 - 25$
	(1)	(2)
Trade via broker (dummy)	-15.5547***	-17.8374***
	(-7.1816)	(-7.3865)
Trade size (log)	0.7485	2.1969**
	(0.6147)	(2.6672)
Volatility (dummy)	-9.3531*	-8.6514
	(-2.0974)	(-1.4981)
Aggregate order flow (bn EUR)	-3.1218**	-2.2699**
	(-3.0985)	(-2.7372)
Order book imbalance (mn EUR)	-0.0181	0.0029
	(-0.3115)	(0.0405)
Inventory	-0.0366	-0.0445
	(-1.3526)	(-1.5550)
Price impact (15min, in bp)	-0.2014	-0.2099
	(-1.1302)	(-1.4415)
Order splitting (dummy)	-2.3398	-1.7795
	(-1.1992)	(-1.1571)
MTS half-spread (bp)	2.1104***	1.9280***
	(6.3716)	(5.3065)
Depth at MTS best (log)	0.6755	1.4553
	(0.4574)	(1.1612)
R^2	0.1246	0.1316
R^2_{adjusted}	0.1018	0.1061
R^2_{within}	0.0776	0.0869
N	5,204	4,492
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	yes	yes

Table VII. Probit model for Venue Choice: MTS vs. OTC. Marginal effects at means of a probit model for the choice of trading on MTS or over-the-counter. Based on the estimation of $Pr(MTS_n) = f(\omega_n)$, where the left-hand variable takes the value one if trade n took place on the exchange MTS and zero otherwise (i.e. MTS_n is zero for bilateral OTC trades, trades via brokers and trades on other platforms than MTS), and ω_n is a vector of trade and bond characteristics. The sample consists of trades between MTS dealers during MTS hours. The minimum trade size is 2 million EUR in all specifications and in specification (2) we further constrain the sample to trades for, at most, 25 million EUR. Control variables not shown account for bond age, logarithmic amount outstanding, coupon rate, on-the-run status, a dummy controlling for issuance days, and end-of-quarter and end-of-year effects. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Z-scores are given in brackets where standard errors are clustered at the dealer level and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Interdealer trades	MTS vs. bilat./broker	
Sample: Trade size (million EUR):	≥ 2	$2-25$
	(1)	(2)
Trade size (log)	-0.0938***	-0.1041***
	(-3.6348)	(-3.1615)
Volatility (dummy)	0.0644***	0.0776***
	(15.9893)	(16.5033)
Expected OTC discount	-0.0194**	-0.0241**
	(-2.2289)	(-2.1865)
Dealer volume (tn EUR)	0.1436	0.1746
	(1.5817)	(1.5413)
Aggregate order flow (bn EUR)	0.0047	0.0064
	(0.6165)	(0.6601)
Order book imbalance (mn EUR)	-0.0004**	-0.0002
	(-2.0854)	(-1.2199)
Inventory	-0.0000	-0.0000
	(-1.0447)	(-0.7001)
Price impact (15min, in bp)	0.0031***	0.0037***
	(5.0509)	(4.9619)
Order splitting (dummy)	0.0357***	0.0448***
	(4.9086)	(5.0131)
MTS half-spread (bp)	-0.0118***	-0.0140***
	(-6.4230)	(-5.9041)
Depth at MTS best (log)	-0.0036	-0.0120
	(-0.4251)	(-1.2930)
Cheapest-to-deliver (dummy)	-0.0477***	-0.0545***
	(-4.3290)	(-3.6485)
2-year Schatz (dummy)	0.0845***	0.1026***
	(5.9977)	(5.8096)
5-year Bobl (dummy)	0.0218**	0.0273*
	(2.1632)	(1.9407)
30-year Bund (dummy)	0.1503***	0.1733***
	(5.7375)	(4.6780)
R^2_{pseudo}	0.3253	0.2973
N	13,174	10,490
Controls	yes	yes

Table VIII. Probit model for Venue Choice: via broker vs. bilaterally negotiated OTC. Marginal effects at means of a probit model for the choice of trading OTC via a broker or bilateral negotiation, given that the trade is not sent to the exchange. Based on the estimation of $Pr(broker_n) = f(\omega_n)$, where the left-hand variable takes the value one if trade n took place between a dealer and an interdealer broker and zero otherwise (i.e. $broker_n$ is zero for bilateral OTC trades), and ω_n is a vector of trade and bond characteristics. The sample consists of trades between MTS dealers during MTS hours. The minimum trade size is 2 million EUR in all specifications (1) and in specification (2) we constrain the sample to trades for 2-25 million EUR. Control variables not shown account for bond age, logarithmic amount outstanding, coupon rate, on-the-run status, a dummy controlling for issuance days, and end-of-quarter and end-of-year effects. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Z-scores are given in brackets where standard errors are clustered at the dealer level and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Interdealer trades	broker vs. bilateral	
Sample: Trade size (million EUR):	≥ 2	$2-25$
	(1)	(2)
Trade size (log)	0.1308***	0.1052**
	(9.0295)	(2.5285)
Volatility (dummy)	0.0379	0.0537
	(0.9296)	(1.0826)
Expected OTC discount	0.0121	0.0180
	(0.7925)	(1.0412)
Dealer volume (tn EUR)	0.3942***	0.4000**
	(2.6147)	(2.3832)
Aggregate order flow (bn EUR)	0.0217	0.0136
	(1.3452)	(0.7932)
Order book imbalance (mn EUR)	-0.0002	-0.0003
	(-0.9861)	(-0.8484)
Inventory	0.0002	0.0003
	(1.0841)	(1.4108)
Price impact (15min, in bp)	-0.0016	-0.0012
	(-1.0353)	(-0.8153)
Order splitting (dummy)	0.0162	0.0042
	(0.7322)	(0.1719)
MTS half-spread (bp)	-0.0039*	-0.0031
	(-1.8205)	(-1.5877)
Depth at MTS best (log)	0.0243***	0.0309***
	(3.7191)	(3.1759)
Cheapest-to-deliver (dummy)	0.0917***	0.1000***
	(6.2573)	(4.3655)
2-year Schatz (dummy)	-0.0966	-0.1351
	(-1.1307)	(-1.2969)
5-year Bobl (dummy)	-0.0133	-0.0175
	(-0.2093)	(-0.2320)
30-year Bund (dummy)	0.2579**	0.2853**
	(2.3599)	(2.1723)
R^2_{pseudo}	0.1417	0.0905
N	11,975	9,314
controls	yes	yes

Appendix A. Alternative Definitions of OTC Discount

To ensure the robustness and relevance of our results, we consider two alternative definitions of OTC discount.

Walking Up The Book. First, we explicitly account for the feature of exchange markets that trades larger than the quantity quoted at the respective best level of the limit order book also consume liquidity from deeper levels of the limit order book. This implies that such trades automatically incur higher transaction costs and is often referred to as "walking up the book". In practice, traders try to overcome the added cost by splitting larger orders into multiple, sequentially executed, orders, and/or conditioning trade sizes on the volume available in the order book. We therefore deem the comparison to the best levels of the limit order book the most economically meaningful, and present an alternative specification that takes into account the effects of walking up the book here.

To this end, we re-define OTC discount (originally defined in Equation (1) in Section III) as

$$OTC\ discount = \frac{\epsilon\left(price^{\text{virtual,MTS}} - price^{\text{observed, OTC}}\right)}{\left\|price^{\text{virtual,MTS}} - price^{\text{mid,MTS}}\right\|}\quad , \tag{A1}$$

where $price^{\text{observed, OTC}}$ is the price of an over-the-counter trade observed in our transaction data and $price^{\text{virtual,MTS}}$ is a virtual price which the same trade would have incurred on MTS at the same time. Crucially, $price^{\text{virtual,MTS}}$ is no longer the price at the respective best level but takes into account the complete depth of the full limit order book. As before, $price^{\text{mid,MTS}}$ is the MTS mid-price at the time of the trade, and the trade sign ϵ is $+1$ (-1) for buyer- (seller-) initiated trades and inferred by comparing to the contemporaneous MTS mid-price. The denominator in Equation (A1) is equal to the effective half-spread on MTS, and by our trade sign identification OTC discount is bounded from above by 100%. Since the discount of MTS trades is by definition equal to zero, we only consider the OTC discount of over-the-counter trades and trades on platforms other than MTS.

Table A.1 provides summary statistics for OTC discount as defined in Equation (A1) across the subsamples used in Tables I and II. OTC discount increases when including the effect of walking up the book (i.e. comparing to Table II). This is a mechanical effect due to our updated definition. For larger trades the comparison transaction cost on MTS becomes higher and thus OTC discount with respect to this comparison increases. Relatedly, also the share of OTC trades at an OTC premium is smaller as size effects are taken into account, and this reduction of OTC premia is especially strong for broker trades that are, on average, larger. The average OTC discount of bilateral interdealer trades of 54.5% is larger than the 44.7% for interdealer trades via brokers. Figure A.1 shows the histogram of OTC discount for both bilateral and broker OTC trades in Panel

(a) and (b) respectively. As before (in Figure 2), the distribution of OTC discount in broker trades is less right-skewed and exhibits a discernible peak at zero discount, though both differences are slightly less pronounced.

Table A.2 presents the results of regressing OTC discount as defined in Equation (A1) on proxies of market and information frictions as described in Section V and Table V for our main definition of OTC discount. Most results are similar and change only in magnitude. The most notable change is for trade size, which now has a positive coefficient that is significant at the 1% level for all specifications. This is due to our updated definition, since for larger trades the comparison transaction cost on MTS is higher and thus OTC discount with respect to this comparison increases. Accordingly, the estimation coefficient is also larger for broker trades (which are, on average, larger) and when we do not impose an upper limit on trade size. Depth at the best level of the order book becomes significant and implies that discount is smaller when the book is deep, in agreement with our reasoning above. Other results are in line with our main specification. The effects of volatility and aggregate order flow are of similar magnitude and significance, as are those for the information proxies of price impact and order splitting. The imbalance of the order book is not a significant driver of OTC discount and neither is inventory.

In Table A.3 we present the results of regressing OTC discount as defined in Equation (A1) on the matched sample described in Section V.B. A dummy for broker trades in the regression captures the difference in OTC discount between otherwise similar bilateral and broker OTC trades. We find that broker trades feature, on average, $14.1 - 16.5$ percentage points less discount and significantly so. Despite the altered definition of OTC discount, the result is very similar to the $15.6 - 17.8$ percentage points difference obtained in Section V.B and Table VI, confirming the robustness of our results to size effects.

Normalizing by Price Levels. Secondly, we take a pricing point of view instead of focusing on transaction costs. Accordingly, we re-define OTC discount (originally defined in Equation (1) in Section III) as

$$OTC\ discount = \frac{\epsilon \left(price^{\text{virtual,MTS}} - price^{\text{observed, OTC}} \right)}{price^{\text{mid,MTS}}}, \tag{A2}$$

where $price^{\text{observed, OTC}}$ is the price of an over-the-counter trade observed in our transaction data and $price^{\text{virtual,MTS}}$ is a virtual price which the same trade would have incurred on MTS at the same time. $price^{\text{mid,MTS}}$ is the MTS mid-price at the time of the trade, and the trade sign ϵ is $+1$ (-1) for buyer- (seller-) initiated trades and inferred by comparing to the contemporaneous MTS mid-price. As the reference price we use the quoted price at the respective best level of the limit order book, i.e. $price^{\text{virtual,MTS}}$ is the best ask (bid) price for buyer- (seller-) initiated trades, thereby disregarding effects of walking up the book. Crucially, the denominator in Equation (A2) is no longer equal to the quoted half-spread on MTS but is the mid-price of the bond. OTC discount can thus be interpreted as the discount as a share of the asset price. As before, we only consider the discount of OTC trades.

Table A.4 presents summary statistics for OTC discount normalized by price. The average OTC discount in interdealer trades is 2.4 basis points of mid-price, and again we observe that, on average, OTC discount is larger for bilateral OTC trades (2.7 basis points) than for trades via broker (2.2 basis points) in interdealer trades. Figure A.2 illustrates the two distributions.

Table A.5 presents the results of regressing OTC discount as defined in Equation (A2) on proxies of market and information frictions as described in Section V and Table V for our main definition of OTC discount. Notably R^2 increases from 10-13% (in Table V) to 69-79%. t-values in the regression suggest that this is due to the explanatory power of MTS half-spread. This is unsurprising considering that we removed a normalization by the half-spread and suggests that the latter was indeed performing well. Neglecting these effects, we still find our previous findings confirmed. We abstain from comparing coefficient magnitudes, since our definition of OTC discount has changed greatly. The volatility effect is still present and significant at the 1% level throughout specifications, i.e. when immediacy reduces outside options, dealers obtain lower discounts. For specifications (1) and (2) we also obtain the expected effects due to trade size and market pressures from aggregate order flow. With respect to information frictions, only order splitting is significant at at least the 5% level in the specifications for bilateral trades, but not price impact.

Table A.6 presents the results of regressing OTC discount normalized by price on the matched sample described in Section V.B. The dummy for broker trades indicates that broker trades receive, on average, $0.48 - 0.55$ basis points (of mid-price) less discount than comparable bilateral OTC trades, in line with our previous findings.

In summary, both analyses confirm that our findings are robust to alternative definitions of our variable of interest and confirm our reasoning for the choice of variable. Also, the finding of Section V.B that broker trades are more costly than comparable bilateral OTC trades is robust to the two alternative specifications considered here.

Appendix B. Sample Selection Bias

In this section we take into account that OTC discount may be biased due to the venue choice of dealers. This creates an endogeneity or sample selection bias that we control for following the approach of Madhavan and Cheng (1997); Bessembinder and Venkataraman (2004) and Hendershott and Madhavan (2015), that is we use a two-stage switching model.[40] In the first stage the dealer decides to trade in segment k, $k \in \{bilateral, broker\}$,

[40]Loosely following the notation of Greene (2017).

if $z_k^* > 0$. Since $z^* = \omega_1'\gamma + \varepsilon_1$ is unobserved, we estimate instead a probit model for the binary choice whether a trade happens in segment k or not:

$$Prob(z|\omega_1) = \Phi(\omega_1'\gamma_1), \tag{B1}$$

where z is 1 for a trade in the respective segment and zero otherwise, and ω_1 contains a set of explanatory variables, while the index 1 refers to the first stage. The second stage consists of regressing OTC discount

$$OTC\ discount = \omega_2'\gamma_2 + \epsilon_2 \text{ observed only if } z = 1. \tag{B2}$$

Under the assumption of joint normality of ϵ_1 and ϵ_2 ($\sim [0, 0, \sigma_\epsilon, 1, \rho]$) this setup allows to estimate

$$\mathbb{E}\left[OTC\ discount_n | z_n = 1, \omega_1, \omega_2\right] = \omega_2'\gamma_2 + \rho\sigma_\epsilon\lambda(\omega_1'\gamma_1). \tag{B3}$$

with λ the "Inverse Mills Ratio".

Using this approach we re-estimate the drivers of OTC discount analogous to Table V in Section V. In the first stage we estimate a probit model as in Section VI, where the dependent variable z is 1 for bilateral (broker) OTC trades and zero otherwise. Since the first stage is very similar to Section VI, we refrain from presenting the results again here.

Table A.7 presents the results of regressing OTC discount (as defined in Equation (1 in Section III) on proxies of market and information frictions while controlling for sample selection bias (variable *Inv Mills bilateral* and *Inv Mills broker* respectively). We obtain similar results also when controlling for endogenous venue selection. The estimation coefficients for volatility and aggregate order flow are similar in magnitude and significance to our previous results. We find a significant effect for trade size in specifications (2) - (4), i.e. larger trades (with less outside options) indeed receive a lower discount when controlling for sample selection. The sign for inventory is positive as expected for bilateral trades in specification (1), but of the opposite sign for broker trades in specifications (3) and (4). Likewise for information frictions we retain most of our results. While the dummy for order splitting bcomes insignificant in specification (1), it is now also significant at the 5% and 10% levels in specifications (3) and (4) respectively. Therefore, dealers might be able to detect order splitting even when trades are routed via brokers.

Appendix C. Subsample Stability

Our sample period from 2011 through 2017 encompasses two notable events with an impact on European debt markets: the European sovereign debt crisis and the Public Sector Purchase Programme (PSPP) of the Eurosystem with significant purchases of German Bunds from March 2015 onwards. Figure A.3 shows considerable variation in trading volumes and volume shares of the exchange and OTC segments over our sample period without ,however, indicating any significant breaks or changes in market structure.

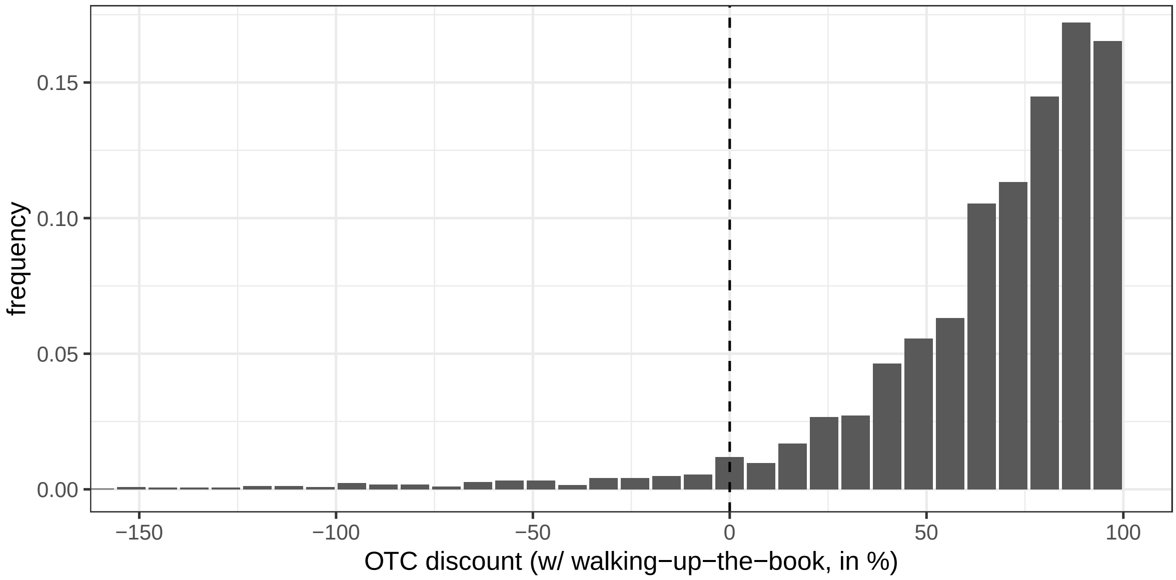
Panel (a) of Figure A.3 shows the annual interdealer volume we observe via our sample. During the crisis in 2011 and 2012, volumes are actually lowest at around 40 billion EUR annually, more than doubling to around 90 billion EUR in 2013 - 2015 and falling to around 60 billion EUR in 2016 and 2017. Panel (b) illustrates that there is also some variation in the share of volume that is traded on the exchange, bilaterally or via brokers. The share of interdealer brokers is highest in 2014 and decreases both towards the beginning and the end of our sample. The exchange MTS has a consistently small share, which is highest in 2011, while the remaining bilateral trades vary accordingly, making up a larger volume share towards the beginning and the end of our sample period.

Tables A.8 and A.9 present the results of regressing OTC discount (as defined in Equation (1 in Section III) on proxies of market and information frictions as described in Section V and Table V. Here we restrict the sample period in Table A.8 to January 2013 through December 2017 to exclude the European debt crisis, and to June 2011 through December 2014 in Table A.9 in order to exclude the Quantitative Easing (QE) program of the ECB.

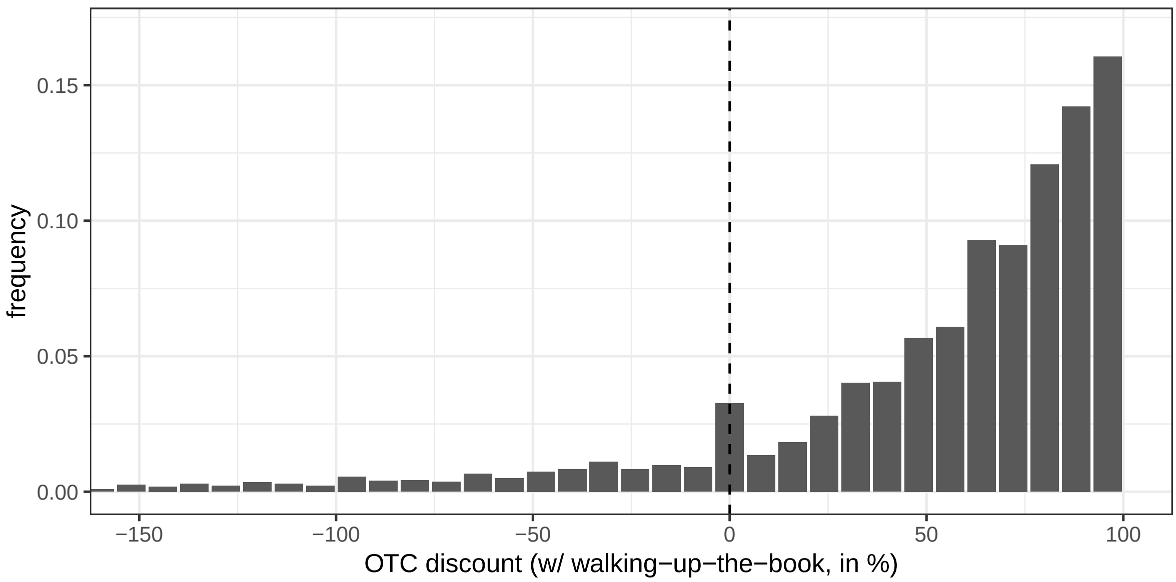
Results for both tables are very similar to those reported in the main regression on our full sample. We therefore dismiss concerns that our results are only due to extreme events in our sample period. Unfortunately, a further breakdown into shorter time periods is not sensible due to the limited number of observations.

Tables A.10 and A.11 present the results of repeating the regression of OTC discount on the matched sample described in Section V.B, where the matched sample is restricted to the respective shortened sample periods described above. For both samples the results are in line with our previous findings. Excluding the crisis period in Table A.10, we still find that OTC discount of interdealer broker trades is, on average, $15.6-18.4$ percentage points lower than for bilateral trades. The corresponding result is $20.1-22.6$ percentage points when excluding the QE period, and all coefficients are highly significant and in line with the difference of $15.6-17.8$ percentage points we obtained in Table VI. Therefore, also the finding of Section V.B that broker trades are more costly than comparable bilateral OTC trades is robust when considering the shorter sample periods.

Figure A.1. Histogram of OTC Discount: with walking up the book. *OTC discount*, defined in Equation (A1) in the Appendix, is the difference in price between the observed price of an OTC trade and the price the same trade would have incurred on MTS, symmetrized for buy and sell trades and normalized by the effective MTS half-spread for the same trade. *OTC discount* captures how much the transaction cost of OTC trades was lower than on MTS and is given in units of %. Differently from our main specification in the paper, *OTC discount* here explicitly takes into account that large trades "walk up the book" and incur higher costs on the exchange. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. OTC discount is bounded from above to be at most 100%. The figure shows the distribution of OTC discount based on interdealer trades of nominal size of at least 2 million EUR. Panel (a) refers to bilateral OTC trades and Panel (b) to trades via a broker. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

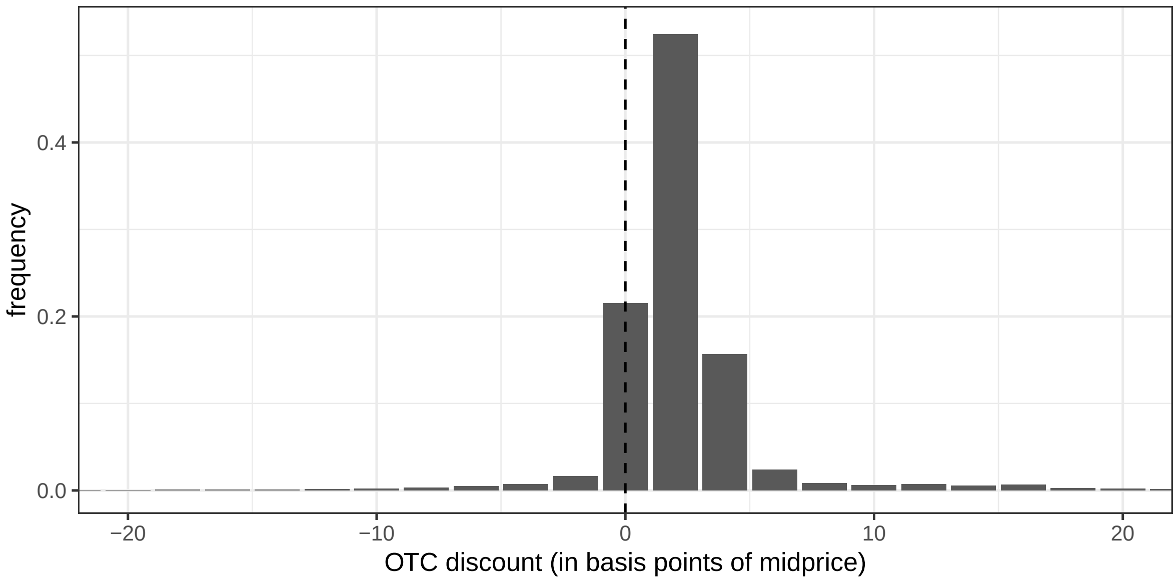


(a) Interdealer trades via bilateral OTC.

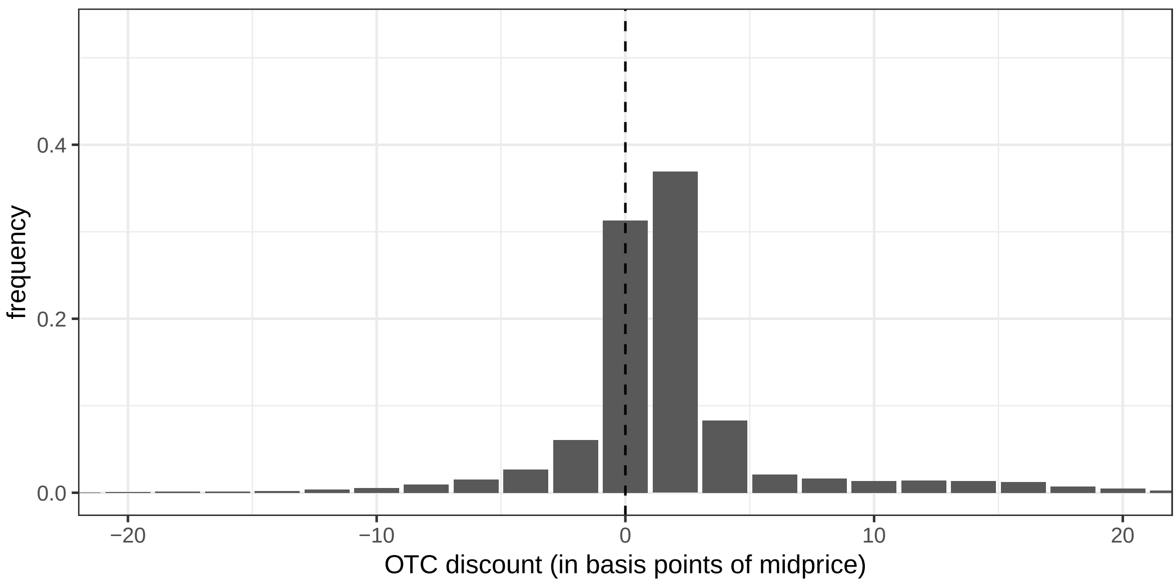


(b) Interdealer trades via broker.

Figure A.2. Histogram of OTC Discount normalized by Price. *OTC discount*, defined in Equation (A2) in the Appendix, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the quoted mid-price on MTS. It is given in units of %. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. The figure shows the distribution of OTC discount based on interdealer trades of nominal size of at least 2 million EUR. Panel (a) refers to bilateral OTC trades and Panel (b) to trades via a broker. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

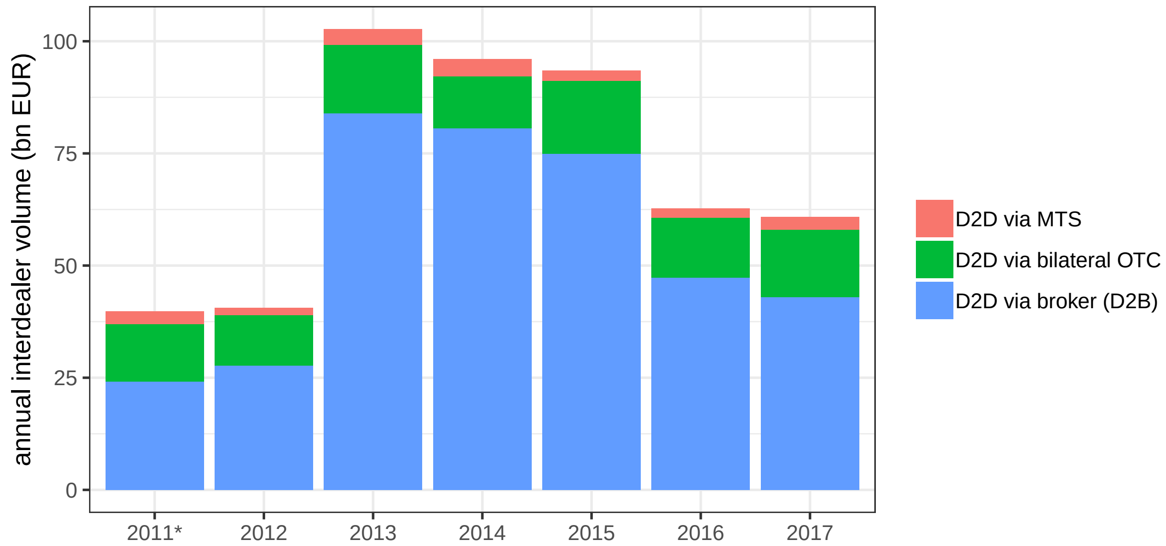


(a) Interdealer trades via bilateral OTC.

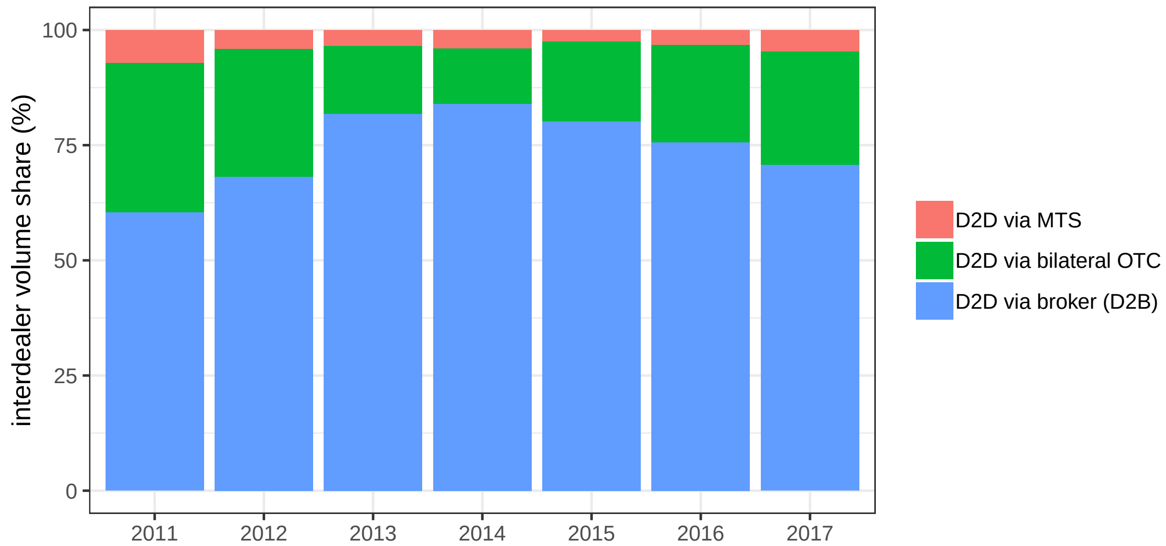


(b) Interdealer trades via broker.

Figure A.3. Annual Interdealer Trading Activity: Panel (a) shows the annual interdealer trading volume in our regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. The figure distinguishes between interdealer trading via the exchange MTS, bilaterally between dealers or facilitated by interdealer brokers. Panel (b) gives the annual volume shares for each of these segments in percent. Interdealer volume in Panel (a) is given in billion EUR and the numbers for the year 2011 have been extrapolated to represent the full year.



(a) Annual interdealer trading volume (rescaled for 2011).



(b) Annual volume share of interdealer trading activity by segment.

Table A.1. Descriptive Statistics of OTC Discount: with walking up the book. *OTC discount*, defined in Equation (A1) in the Appendix, is the difference in price between the observed price of an OTC trade and the price the same trade would have incurred on MTS, symmetrized for buy and sell trades and normalized by the effective MTS half-spread for the same trade. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of %. Differently from our main specification in the paper, *OTC discount* here explicitly takes into account that large trades "walk up the book" and incur higher costs on the exchange. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. OTC discount is bounded from above to be, at most, 100%. Reported are summary statistics of OTC discount for the subsets defined in Table I, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. The column p-value gives the p-value for a t-test of the mean being different from zero and *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount to best (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,024	34.91	246.25	-96.25	36.00	67.14	85.71	96.67	12.30	0.0000
trade size $\geq$ 2 million EUR	176,277	38.61	318.93	-80.00	40.00	70.00	86.54	96.97	11.36	0.0000
init. & counterp. ID known	101,148	39.48	304.38	-71.11	40.00	70.00	86.67	96.92	10.75	0.0000
D2D	23,526	48.20	100.26	-66.97	41.94	70.81	86.94	97.24	10.54	0.0000
D2D via bilateral OTC	8,328	54.53	128.53	-15.50	52.00	74.26	88.00	96.89	6.02	0.0000
D2D via broker (D2B)	15,198	44.73	80.47	-92.00	34.21	68.00	86.35	97.50	13.01	0.0000

Table A.2. Drivers of OTC Discount: with walking up the book. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (A1) in the Appendix, is the difference in price between the observed price of an OTC trade and the price the same trade would have incurred on MTS, symmetrized for buy and sell trades and normalized by the effective MTS half-spread for the same trade. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of %. Differently from our main specification in the paper, *OTC discount* here explicitly takes into account that large trades "walk up the book" and incur higher costs on the exchange. On the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral OTC trades between MTS dealers in specifications (1) and (2), and trades between MTS dealers and interdealer brokers in specifications (3) and (4). The minimum trade size is 2 million EUR in all specifications, and in specifications (2) and (4) we further constrain the sample to trades of size 2-25 million EUR. Control variables not shown account for bond age, on-the-run status, cheapest-to-deliver status, a dummy controlling for issuance days, end-of-quarter or end-of-year effects, whether trade size was a "round" amount, and for whether a trade took place on a platform other than MTS. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at daily time, bond and dealer level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Market segment: Interdealer trades	bilateral OTC		via broker	
Trade size (million EUR):	≥ 2	$2-25$	≥ 2	$2-25$
	(1)	(2)	(3)	(4)
Trade size (log)	4.6999***	3.6133***	9.5344***	6.2009***
	(6.5074)	(5.7969)	(9.8400)	(3.8440)
Volatility (dummy)	-11.0199***	-10.4673***	-8.5628**	-9.2180**
	(-4.1550)	(-3.6185)	(-2.7594)	(-2.9538)
Aggregate order flow (bn EUR)	-2.8350***	-2.7093***	-2.6048***	-3.0823***
	(-4.2636)	(-4.0558)	(-5.5499)	(-4.0187)
Order book imbalance (mn EUR)	-0.0376	-0.0480	0.0152	-0.0002
	(-1.1087)	(-1.6347)	(0.6377)	(-0.0042)
Inventory	0.0026	-0.0030	-0.0028	0.0033
	(0.3726)	(-0.5240)	(-0.2660)	(0.2821)
Price impact (15min, in bp)	-0.2365**	-0.2228**	-0.0701	-0.0858
	(-2.2909)	(-2.0439)	(-0.9943)	(-1.1228)
Order splitting (dummy)	-3.0009**	-3.2222**	-0.0891	-0.2064
	(-2.5111)	(-2.6496)	(-0.1232)	(-0.2251)
MTS half-spread (bp)	1.7101***	1.7449***	0.9214***	0.9997***
	(6.0952)	(5.5068)	(4.0411)	(3.7610)
Depth at MTS best (log)	-3.0027***	-2.6632***	-4.9866***	-4.9912***
	(-5.3246)	(-4.8201)	(-12.0320)	(-10.2647)
R^2	0.0995	0.0951	0.2083	0.1484
R^2_{adjusted}	0.0802	0.0746	0.1999	0.1353
R^2_{within}	0.0454	0.0370	0.1014	0.0508
N	7,825	7,295	13,586	9,266
Bond FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
Controls	yes	yes	yes	yes

Table A.3. Drivers of OTC Discount with walking up the book: Matched sample of bilateral / broker OTC trades. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (A1) in the Appendix, is the difference in price between the observed price of an OTC trade and the price the same trade would have incurred on MTS, symmetrized for buy and sell trades and normalized by the effective MTS half-spread for the same trade. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of %. Unlike our main specification in the paper, *OTC discount* here explicitly takes into account that large trades "walk up the book" and incur higher costs on the exchange. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS, whereas on the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral and broker OTC trades between MTS dealers. The trades are matched along the dimensions of trade size, MTS (half-)spread, date, bond (ISIN) and initiating dealer. Further details of the matching process are described in Section V.B. The minimum trade size is 2 million EUR in all specifications, and in specification (2) we further constrain the sample to trades of size 2-25 million EUR. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, dealer and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Trade size (million EUR):	≥ 2	$2-25$
	(1)	(2)
Trade via broker (dummy)	-14.1384***	-16.5473***
	(-6.5089)	(-7.1606)
Trade size (log)	8.8411***	7.1624***
	(10.6676)	(7.2547)
Volatility (dummy)	-8.3980	-8.8377
	(-1.9169)	(-1.6995)
Aggregate order flow (bn EUR)	-2.6019**	-2.2352**
	(-2.8542)	(-2.7543)
Order book imbalance (mn EUR)	-0.0093	-0.0101
	(-0.1583)	(-0.1664)
Inventory	-0.0279	-0.0391
	(-1.1361)	(-1.6554)
Price impact (15min, in bp)	-0.2012	-0.1927
	(-1.0800)	(-1.0308)
Order splitting (dummy)	-0.9507	-1.4630
	(-0.7344)	(-1.0410)
MTS half-spread (bp)	1.5410***	1.6016***
	(5.8677)	(5.0963)
Depth at MTS best (log)	-4.2418**	-3.6469**
	(-3.2086)	(-3.2234)
R^2	0.1538	0.1404
R^2_{adjusted}	0.1318	0.1152
R^2_{within}	0.1057	0.0960
N	5,204	4,492
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	yes	yes

Table A.4. Descriptive Statistics of OTC Discount normalized by Price. *OTC discount*, defined in Equation (A2) in the Appendix, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the quoted mid-price on MTS. It is given in units of basis points. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. Reported are summary statistics of OTC discount for the subsets defined in Table I, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. The column p-value gives the p-value for a t-test of the mean being different from zero and *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount normalized by price (in basis points)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,033	3.85	53.45	-3.09	0.78	1.88	3.36	15.55	13.52	0.0000
trade size ≥ 2 million EUR	176,279	2.25	26.85	-3.11	0.60	1.69	2.89	11.84	14.39	0.0000
init. & counterp. ID known	101,149	2.39	30.75	-2.81	0.70	1.73	2.94	11.83	13.52	0.0000
D2D	23,527	2.40	27.92	-3.27	0.57	1.53	2.72	11.62	15.04	0.0000
D2D via bilateral OTC	8,328	2.72	41.28	-0.78	0.99	1.84	2.86	6.49	7.34	0.0000
D2D via broker (D2B)	15,199	2.23	16.52	-4.21	0.24	1.30	2.62	13.28	19.26	0.0000

Table A.5. Drivers of OTC Discount normalized by Price. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (A2) in the Appendix, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the quoted mid-price on MTS. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of basis points. On the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral OTC trades between MTS dealers in specifications (1) and (2) and trades between MTS dealers and interdealer brokers in specifications (3) and (4). The minimum trade size is 2 million EUR in all specifications, and in specifications (2) and (4) we further constrain the sample to trades of size 2-25 million EUR. Control variables not shown account for bond age, on-the-run status, cheapest-to-deliver status, a dummy controlling for issuance days, end-of-quarter or end-of-year effects, whether trade size was a "round" amount, and for whether a trade took place on a platform other than MTS. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at daily time, bond and dealer level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Market segment: Interdealer trades	bilateral OTC		via broker	
Trade size (million EUR):	≥ 2	$2-25$	≥ 2	$2-25$
	(1)	(2)	(3)	(4)
Trade size (log)	-0.0898***	-0.0571***	-0.0495	-0.1175
	(-2.7646)	(-2.7719)	(-0.8508)	(-1.2041)
Volatility (dummy)	-0.6022***	-0.5901***	-1.0109***	-0.9587***
	(-5.0827)	(-3.4429)	(-4.8256)	(-3.8122)
Aggregate order flow (bn EUR)	-0.1167***	-0.1069***	-0.0889*	-0.1050
	(-3.3421)	(-3.0672)	(-1.9207)	(-1.4359)
Order book imbalance (mn EUR)	-0.0027	-0.0027**	-0.0020	-0.0020
	(-1.5720)	(-2.0827)	(-1.1816)	(-0.6840)
Inventory	0.0005	0.0002	0.0000	0.0002
	(0.6462)	(0.4677)	(0.0198)	(0.1225)
Price impact (15min, in bp)	-0.0182	-0.0155	0.0028	-0.0021
	(-1.5462)	(-1.1672)	(0.1612)	(-0.1100)
Order splitting (dummy)	-0.1524**	-0.1555***	-0.0209	-0.0416
	(-2.6071)	(-2.8379)	(-0.3973)	(-0.5856)
MTS half-spread (bp)	0.6627***	0.6588***	0.5659***	0.5583***
	(25.4922)	(24.2069)	(26.1705)	(26.4607)
Depth at MTS best (log)	-0.0044	0.0002	-0.0644	-0.0813
	(-0.1874)	(0.0064)	(-1.4898)	(-1.5463)
R^2	0.7772	0.7874	0.6885	0.6968
R^2_{adjusted}	0.7725	0.7826	0.6852	0.6921
R^2_{within}	0.5438	0.5510	0.3623	0.3656
N	7,825	7,295	13,586	9,266
Bond FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
Controls	yes	yes	yes	yes

Table A.6. Drivers of OTC Discount normalized by Price: Matched sample of bilateral / broker OTC trades. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (A2) in the Appendix, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the quoted mid-price on MTS. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of basis points. On the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral and broker OTC trades between MTS dealers. The trades are matched along the dimensions of trade size, MTS (half-)spread, date, bond (ISIN) and initiating dealer. Further details of the matching process are described in Section V.B. The minimum trade size is 2 million EUR in all specifications, and in specification (2) we further constrain the sample to trades of size 2-25 million EUR. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, dealer and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Trade size (million EUR):	≥ 2	$2-25$
	(1)	(2)
Trade via broker (dummy)	-0.4755***	-0.5523***
	(-4.9702)	(-5.9134)
Trade size (log)	-0.0259	0.0067
	(-0.4155)	(0.1144)
Volatility (dummy)	-0.6009**	-0.5463*
	(-3.1205)	(-2.4946)
Aggregate order flow (bn EUR)	-0.1265***	-0.1136**
	(-4.1502)	(-3.6019)
Order book imbalance (mn EUR)	-0.0020	-0.0020
	(-0.5408)	(-0.8752)
Inventory	-0.0010	-0.0013
	(-1.0012)	(-0.7273)
Price impact (15min, in bp)	-0.0125	-0.0115
	(-0.8120)	(-0.6906)
Order splitting (dummy)	-0.0801	-0.0509
	(-1.6286)	(-1.2202)
MTS half-spread (bp)	0.6100***	0.6027***
	(13.7964)	(19.6062)
Depth at MTS best (log)	-0.0015	0.0011
	(-0.0211)	(0.0211)
R^2	0.6907	0.7195
R^2_{adjusted}	0.6827	0.7113
R^2_{within}	0.4425	0.4612
N	5,204	4,492
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	yes	yes

Table A.7. Drivers of OTC Discount with Sample Selection Bias Correction. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (1) in Section III, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of %. On the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral OTC trades between MTS dealers in specifications (1) and (2) and trades between MTS dealers and interdealer brokers in specifications (3) and (4). The minimum trade size is 2 million EUR in all specifications, and in specifications (2) and (4) we further constrain the sample to trades of size 2-25 million EUR. The *Inv Mill* terms are selectivity adjustments for the choice of trading bilaterally or via broker respectively. Control variables not shown account for bond age, on-the-run status, cheapest-to-deliver status, a dummy controlling for issuance days, end-of-quarter or end-of-year effects, whether trade size was a "round" amount, and for whether a trade took place on a platform other than MTS. Standard errors are clustered at daily time, bond and dealer level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Market segment: Interdealer trades	bilateral OTC		via broker	
Trade size (million EUR):	≥ 2	$2-25$	≥ 2	$2-25$
	(1)	(2)	(3)	(4)
Trade size (log)	0.2964	-2.1919***	-5.8741***	-9.9211***
	(0.2643)	(-2.6737)	(-4.4445)	(-5.1169)
Volatility (dummy)	-8.0110***	-8.6956***	-9.5900***	-8.2756***
	(-2.7717)	(-4.1138)	(-3.1426)	(-2.7882)
Aggregate order flow (bn EUR)	-3.5790***	-2.9462***	-3.7159***	-3.9008***
	(-4.4406)	(-3.8446)	(-4.2535)	(-4.3332)
Order book imbalance (mn EUR)	-0.0685**	-0.0519*	-0.0154	0.0071
	(-2.5422)	(-1.9773)	(-0.5757)	(0.1846)
Inventory	0.0212**	-0.0059	-0.0366***	-0.0598***
	(2.2129)	(-0.7775)	(-2.8806)	(-3.2402)
Price impact (15min, in bp)	-0.2138**	-0.1830**	-0.0159	0.0490
	(-2.5785)	(-2.1805)	(-0.1962)	(0.6199)
Order splitting (dummy)	-1.5435	-2.4512**	-1.9349**	-1.9486*
	(-1.2262)	(-2.2943)	(-2.1094)	(-1.7050)
MTS half-spread (bp)	1.6428***	1.7293***	1.3604***	0.9618***
	(4.4555)	(5.7731)	(5.5374)	(4.1843)
Depth at MTS best (log)	1.2347*	0.8375	0.6262	0.4201
	(1.7457)	(1.2525)	(0.8643)	(0.4483)
Inv Mills bilateral	-17.2186*	-13.0996***		
	(-1.9646)	(-3.3588)		
Inv Mills broker			-21.3852***	-37.1719***
			(-4.3452)	(-4.9669)
R^2	0.1002	0.1003	0.1367	0.1325
R^2_{adjusted}	0.0809	0.0799	0.1276	0.1192
R^2_{within}	0.0442	0.0407	0.0442	0.0434
N	7,825	7,295	13,592	9,272
Bond FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
Controls	yes	yes	yes	yes

Table A.8. Drivers of OTC Discount: 2013-2017. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (1) in Section III, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of %. On the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral OTC trades between MTS dealers in specifications (1) and (2) and trades between MTS dealers and interdealer brokers in specifications (3) and (4). The minimum trade size is 2 million EUR in all specifications, and in specifications (2) and (4) we further constrain the sample to trades of size 2-25 million EUR. Control variables not shown account for bond age, on-the-run status, cheapest-to-deliver status, a dummy controlling for issuance days, end-of-quarter or end-of-year effects, whether trade size was a "round" amount, and for whether a trade took place on a platform other than MTS. Based on regulatory data of all transactions in German Bunds involving German financial institutions from January 2013 through December 2017. Standard errors are clustered at daily time, bond and dealer level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Market segment: Interdealer trades	bilateral OTC		via broker	
Trade size (million EUR):	≥ 2	$2-25$	≥ 2	$2-25$
	(1)	(2)	(3)	(4)
Trade size (log)	-1.1758	0.1535	-0.4036	-0.5551
	(-1.5197)	(0.2360)	(-0.3038)	(-0.2955)
Volatility (dummy)	-7.8335**	-8.3895**	-12.4991***	-12.1570***
	(-2.6450)	(-2.7202)	(-3.1506)	(-3.2518)
Aggregate order flow (bn EUR)	-3.4782***	-3.1120***	-3.7333***	-3.2696***
	(-3.9343)	(-3.8252)	(-4.7618)	(-3.1038)
Order book imbalance (mn EUR)	-0.0836**	-0.0748	-0.0263	-0.0137
	(-2.4248)	(-1.3293)	(-0.8423)	(-0.2701)
Inventory	0.0071	0.0027	-0.0056	-0.0061
	(0.4915)	(0.1926)	(-0.4181)	(-0.3171)
Price impact (15min, in bp)	-0.3620**	-0.3072	-0.1298	-0.1679
	(-2.2069)	(-1.5540)	(-0.9687)	(-1.3565)
Order splitting (dummy)	-4.0239***	-3.6902***	-0.7332	-0.1193
	(-3.0890)	(-3.0926)	(-0.7560)	(-0.1034)
MTS half-spread (bp)	2.4761***	2.3655***	1.6357***	1.4146***
	(5.4079)	(5.2397)	(4.2812)	(3.4115)
Depth at MTS best (log)	0.3111	0.4260	1.1033	1.7271
	(0.4547)	(0.6036)	(1.2129)	(1.4150)
R^2	0.1080	0.1085	0.1385	0.1364
R^2_{adjusted}	0.0860	0.0854	0.1287	0.1216
R^2_{within}	0.0447	0.0411	0.0421	0.0396
N	6,229	5,785	11,652	7,789
Bond FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
Controls	yes	yes	yes	yes

Table A.9. Drivers of OTC Discount: 2011-2014. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (1) in Section III, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS and is given in units of %. On the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral OTC trades between MTS dealers in specifications (1) and (2), and trades between MTS dealers and interdealer brokers in specifications (3) and (4). The minimum trade size is 2 million EUR in all specifications, and in specifications (2) and (4) we further constrain the sample to trades of size 2-25 million EUR. Control variables not shown account for bond age, on-the-run status, cheapest-to-deliver status, a dummy controlling for issuance days, end-of-quarter or end-of-year effects, whether trade size was a "round" amount, and for whether a trade took place on a platform other than MTS. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2014. Standard errors are clustered at daily time, bond and dealer level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Market segment: Interdealer trades	bilateral OTC		via broker	
Trade size (million EUR):	≥ 2	$2-25$	≥ 2	$2-25$
	(1)	(2)	(3)	(4)
Trade size (log)	-2.1675	-0.0420	0.9620	0.9125
	(-1.2221)	(-0.0316)	(1.1984)	(0.7839)
Volatility (dummy)	-10.2274***	-8.2586**	-9.3985***	-10.6959***
	(-2.9017)	(-2.3787)	(-3.5829)	(-3.4111)
Aggregate order flow (bn EUR)	-3.0076**	-2.2923*	-2.8954***	-3.7060**
	(-2.3317)	(-1.8200)	(-3.9347)	(-2.9234)
Order book imbalance (mn EUR)	-0.0767	-0.0745	0.0090	0.0570
	(-1.6104)	(-1.5520)	(0.2069)	(0.8201)
Inventory	0.0183	0.0069	-0.0026	0.0018
	(1.1984)	(0.6158)	(-0.1467)	(0.0558)
Price impact (15min, in bp)	-0.3412**	-0.2880**	-0.0079	-0.0275
	(-2.5901)	(-2.5129)	(-0.0572)	(-0.2315)
Order splitting (dummy)	-3.2600**	-3.9971***	-1.0865	0.3072
	(-2.2756)	(-2.9845)	(-0.8319)	(0.1600)
MTS half-spread (bp)	2.1763***	2.0785***	1.7290***	1.6155***
	(6.4522)	(5.6986)	(6.9916)	(6.5872)
Depth at MTS best (log)	1.1328	1.4307*	0.6274	1.4722*
	(1.3979)	(1.8180)	(0.8406)	(1.8885)
R^2	0.1311	0.1322	0.1424	0.1370
R^2_{adjusted}	0.1025	0.1019	0.1279	0.1151
R^2_{within}	0.0351	0.0280	0.0205	0.0226
N	4,208	3,977	6,971	4,597
Bond FE	yes	yes	yes	yes
Dealer FE	yes	yes	yes	yes
Controls	yes	yes	yes	yes

Table A.10. Drivers of OTC Discount: Matched sample of bilateral / broker OTC trades: 2013-2017. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (1) in Section III, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. It is given in units of %. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS, whereas on the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral and broker OTC trades between MTS dealers. The trades are matched along the dimensions of trade size, MTS (half-)spread, date, bond (ISIN) and initiating dealer. Further details of the matching process are described in Section V.B. The minimum trade size is 2 million EUR in all specifications, and in specification (2) we further constrain the sample to trades of size 2-25 million EUR. Based on regulatory data of all transactions in German Bunds involving German financial institutions from January 2013 through December 2017. Standard errors are clustered at bond, dealer and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Trade size (million EUR):	≥ 2	$2-25$
	(1)	(2)
Trade via broker (dummy)	-15.6488***	-18.3729***
	(-6.1937)	(-6.1329)
Trade size (log)	1.0800	2.1943*
	(1.1568)	(2.4111)
Volatility (dummy)	-9.9336**	-8.6561**
	(-3.5009)	(-2.6328)
Aggregate order flow (bn EUR)	-4.0537**	-3.2406**
	(-2.9932)	(-2.6678)
Order book imbalance (mn EUR)	-0.0275	0.0006
	(-0.4732)	(0.0058)
Inventory	-0.0323	-0.0390
	(-0.6368)	(-0.9888)
Price impact (15min, in bp)	-0.2740	-0.3621
	(-0.7319)	(-1.0895)
Order splitting (dummy)	-2.2218	-1.7418
	(-1.2464)	(-1.0714)
MTS half-spread (bp)	2.5979***	2.3751**
	(4.9117)	(3.8108)
Depth at MTS best (log)	0.3656	1.2391
	(0.2130)	(0.7948)
R^2	0.1308	0.1410
R^2_{adjusted}	0.1059	0.1124
R^2_{within}	0.0811	0.0939
N	4,270	3,663
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	yes	yes

Table A.11. Drivers of OTC Discount: Matched sample of bilateral / broker OTC trades: 2011-2014. Estimation of $OTC\ discount_n = \Pi v_n + \Delta_b + \Delta_i + \varepsilon_n$. The left hand variable, $OTC\ discount_n$, defined in Equation (1) in Section III, is the difference in price between the observed price of an OTC trade and the price a small trade of the same trade direction would have incurred on MTS, symmetrized for buy and sell trades and normalized by the MTS half-spread. It is given in units of %. $OTC\ discount_n$ captures how much the transaction cost of OTC trade n was lower than on MTS, whereas on the right-hand side v_n is a vector of trade and bond characteristics, and Δ_b and Δ_i are fixed effects for bond (ISIN) and initiating dealer respectively. The sample consists of bilateral and broker OTC trades between MTS dealers. The trades are matched along the dimensions of trade size, MTS (half-)spread, date, bond (ISIN) and initiating dealer. Further details of the matching process are described in Section V.B. The minimum trade size is 2 million EUR in all specifications, and in specification (2) we further constrain the sample to trades of size 2-25 million EUR. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2014. Standard errors are clustered at bond, dealer and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Trade size (million EUR):	≥ 2	$2-25$
	(1)	(2)
Trade via broker (dummy)	-20.0652***	-22.5607***
	(-9.7873)	(-11.9147)
Trade size (log)	0.5226	2.4760
	(0.2358)	(1.5329)
Volatility (dummy)	-2.8165	-3.8969
	(-0.5379)	(-0.6567)
Aggregate order flow (bn EUR)	-2.2658	-0.5235
	(-1.2539)	(-0.3800)
Order book imbalance (mn EUR)	-0.0620	-0.0692
	(-0.5954)	(-0.7952)
Inventory	-0.0108	-0.0253
	(-0.3742)	(-0.5996)
Price impact (15min, in bp)	-0.1951	-0.1886
	(-1.6325)	(-1.1265)
Order splitting (dummy)	-2.4363	-1.6654
	(-1.4484)	(-1.0280)
MTS half-spread (bp)	1.9600***	1.7714**
	(4.7732)	(3.6055)
Depth at MTS best (log)	1.0159	1.8017
	(0.7011)	(1.6221)
R^2	0.1417	0.1561
R^2_{adjusted}	0.1089	0.1208
R^2_{within}	0.0767	0.0925
N	2,908	2,566
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	yes	yes