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Abstract

We document a sizable OTC discount in the interdealer market for German sovereign bonds where exchange and over-the-counter trading coexist: the vast majority of OTC prices are favorable compared to exchange quotes. This is a challenge for theories of OTC markets centered around search-and-bargaining frictions but consistent with models of hybrid markets based on information frictions. We find support for this explanation. Distinguishing between bilateral and broker-intermediated OTC trades, differences in OTC discount across protocols are consistent with their relative informedness. Within each protocol, the difference in OTC discount is explained not only by information but also by search-and-bargaining frictions.

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

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

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1 Introduction

Most fixed-income and derivative instruments trade in over-the-counter (OTC) markets. Participants in these markets search for counterparties and negotiate prices that reflect their relative bargaining positions. However, in some asset classes dealers can also trade with one another on electronic central limit order books provided by exchange platforms. In contrast to OTC markets, search-and-bargaining features are irrelevant on the exchange where all participants can immediately trade at the same prices. In hybrid markets where OTC and exchange platforms co-exist, transaction costs should therefore be higher for OTC trades.

Yet, studying the dealer-to-dealer (D2D) segment of the market for German sovereign bonds (*Bunds*) we document that the vast majority of OTC trades have *lower* transaction costs than exchange quotes, thus giving rise to a pervasive *OTC discount*. This finding is surprising from a search-and-bargaining perspective. However, it is consistent with theories that emphasize the role of information frictions that arise when some market participants are better informed than others and therefore give rise to adverse selection. Our empirical analysis lends support to such an explanation. First, we find that order flow resulting from exchange trading has stronger predictive power for future returns than OTC transactions, suggesting that these trades carry more information. Second, we show that the observed variation in OTC discount across trades is driven by proxies of information frictions. However, we also find a role for proxies of search-and-bargaining, suggesting that both information and search-and-bargaining frictions should be present in theories of hybrid markets.

Our empirical setup has a crucial advantage relative to previous studies addressing similar questions. In the D2D Bund market dealers trade with each other both OTC and on the interdealer exchange MTS. The interdealer Bund market thus represents an ideal laboratory to study dealer pricing and trading decisions in a hybrid market structure. We combine a unique regulatory dataset that comprises *all* trades involving at least one financial institution regulated in Germany with the full limit order book on MTS. This allows us to compute our main quantity of interest, OTC discount, which measures the transaction cost advantage of an OTC trade with respect to the potential execution of the same trade on the exchange at the same time.[1] We find that 87% of interdealer transactions execute at a lower price than the one attainable on MTS, giving rise to an OTC discount of on average 35%. This is highly economically significant in light of an annual trading volume of about 1.6 trillion EUR in the interdealer Bund market.

A unique feature of our data is that we can distinguish between bilateral OTC trades and those routed via interdealer brokers. These intermediaries typically follow a "matched principal" protocol. This implies that the broker acts as a counterparty to both sides of the trade without taking inventory and that the identity of counterparties is not revealed to each other even after the trade is settled. We find that more than three quarters of Bund interdealer volume is broker-intermediated and that on average these trades feature an OTC discount that is about one third lower than for bilaterally negotiated trades. Hence, we observe a pecking order of transactions costs: exchange trading is more expensive than via brokers, and broker-intermediated are more costly than bilateral OTC trades.

Dealers thus face an important trade-off. Trading on the exchange eliminates search-and-bargaining frictions but implies that all market participants instantaneously observe the price and volume of each trade; it thus likely reveals the most information. Trading bilaterally in the OTC market features the highest search costs but reveals little information, as only the involved counterparties are aware of the transaction. Finally, trading via a broker reduces search-and-bargaining costs compared to bilateral trades and provides anonymity to counterparties.

To assess the relative importance of these channels in driving OTC discount, we estimate a transaction-level regression of OTC discount on proxies of information and search-and-bargaining frictions. The analysis is done separately for bilateral and broker-intermediated trades to study the drivers of OTC discount within each trading protocol. We capture informedness via a trade's ex-post price impact and the occurrence of order splitting. We

[1] Cenedese, Ranaldo and Vasios (2020) use similar terminology in their analysis of interest rate swaps. These contracts are traded in an OTC market, with some trades cleared via central counterparties (CCPs) and others not. They document that the same derivative contract is more expensive when not cleared via a CCP and label these price differentials *OTC premia*.

proxy search-and-bargaining frictions with factors influencing the outside options available to dealers. More informed OTC trades receive significantly lower discounts. At the same time, traders with more bargaining power receive higher discounts, suggesting that both types of frictions are quantitatively important drivers of OTC discount.

Importantly, our results account for the potential endogeneity arising from the joint determination of the choice of trading protocol and pricing decisions. Specifically, we first study dealers' protocol choice at the level of individual trades and account for this choice in the OTC discount analysis described above. We find that more informed transactions are more likely to be routed via the exchange than traded OTC. Among OTC trades, transactions with greater information content are more likely to be executed via a broker.

While our transaction-level analysis captures variation in OTC discount *within* trading protocols, it does not fully explain the average difference in OTC discount *across* protocols. We therefore study the aggregate informational content of each protocol by regressing bond returns on the lagged order flows from exchange trades and bilateral and broker-intermediated OTC transactions. We show that the order flows from both the exchange and broker trading predict bond returns a few days out and that this effect is slightly stronger for the flow from the exchange. We find no predictability for the flow from bilateral interdealer trades. These findings are consistent with our results regarding dealers' protocol choice. Crucially, both results are in line with the observed pecking order of OTC discount and the view that protocols with greater information content have higher transaction costs.

Our paper contributes to several strands of the literature. There is a long-standing interest in the functioning of OTC markets. Theories of such markets focus on search-and-bargaining frictions to explain pricing differences (e.g. Duffie, Gârleanu and Pedersen, 2005, 2007; Üslü, 2019; Hugonnier, Lester and Weill, 2020). The empirical literature has confirmed the relevance of these frictions, for example with regard to dealer network structure (Li and Schürhoff, 2019) and systematic changes in yield spreads (Friewald and Nagler, 2019). As a result, it is a widely held view that pure exchange markets feature lower transaction costs than pure OTC markets (Edwards, Harris and Piwowar, 2007; Bessembinder, Spatt and Venkataraman, 2020).

Our finding that OTC transaction costs for Bunds are lower than on the exchange may therefore appear surprising. That said, our setting is different from those studied in the papers cited above, because we compare OTC and exchange protocols *co-existing* in a hybrid market. Theories of such hybrid markets commonly rely on information frictions as the relevant driver of transaction costs (Seppi, 1990; Grossman, 1992; Lee and Wang, 2017). Several papers have empirically studied pricing in hybrid markets. Barclay, Hendershott and Kotz (2006) analyze the choice between electronic and voice brokerage for U.S. Treasuries that go off-the-run and Hendershott and Madhavan (2015) study U.S. corporate bonds trading both OTC and on a request-for-quote (RFQ) platform. Studying the market for index CDS, Riggs, Onur, Reiffen and Zhu (2020) focus on the strategic choices of dealers and customers in trading via RFQ or request-for-streaming protocols, whereas Collin-Dufresne, Junge and Trolle (2020) report that in the interdealer segment low-cost, low-immediacy protocols are preferred to trading in a limit order book. A number of papers have analyzed upstairs markets for equities (e.g., Bessembinder and Venkataraman, 2004). More recently, Menkveld, Yueshen and Zhu (2017) document that volatility shocks shift market shares between dark and lit venues along a pecking order based on cost and immediacy.

A key advantage of our analysis with respect to the aforementioned papers is that we can directly compare transaction costs for exchange and OTC trading in a setting that is consistent with existing theories of hybrid markets. A related recent paper in that regard is Holden, Lu, Lugovskyy and Puzzello (2021), who study the introduction of OTC trading to the Chinese interbank FX market and provide evidence for the role of bargaining power by comparing the aggregate price functions of small and large banks. While we do not observe the introduction of a new trading protocol, the data we use in our analysis have several important advantages. First, we can measure transactions costs and the relevant frictions at the trade rather than the aggregate level. Second, we analyze a mature market with an established structure over a period of several years and account for the endogeneity of venue choice and pricing decisions.

We also contribute to the literature on the role of brokers as intermediaries. In the equity market Barbon, Di Maggio, Franzoni and Landier (2019) and Di Maggio, Franzoni, Kermani and Sommavilla (2019) document that brokers leak private information from informative trades to their institutional clients, while Han, Kim and Nanda (2018) argue that brokers help facilitate liquidity provision. In the U.S. Treasury market, Anderson and Liu (2019) show that brokerage platforms help dealers manage their interest rate risk. We document that brokers play a key role also in the Bund market, as they represent the most actively used interdealer trading protocol. In particular, dealers benefit from the anonymity and facilitation of large orders provided by brokers. Brokers are not unique to the Bund market but are also an integral part of other interdealer fixed-income markets, such as U.K. Gilts (Holland, 2001) and Canadian sovereign bonds (Berger-Soucy, Garriott and Usche, 2018). Our results thus highlight that understanding the role of brokers is crucial for modeling the microstructure of sovereign debt markets.

Our finding of a sizable OTC discount being driven by information is surprising from the point of view of the Bund as a safe asset (Gorton, 2017), where private information about the fundamental value should be negligible. However, even in the absence of private information about fundamental asset values, information related to order flows can be important (Burdett and O'Hara, 1987; Brancaccio, Li and Schürhoff, 2020; Colliard and Demange, 2021). For example, in the model of Grossman (1992) dealers' knowledge of "unexpressed order flow" allows them to provide better trading conditions over-the-counter than on the exchange. For safe and highly liquid assets such as Bunds, this is likely to be the relevant information to which dealers have access. In the Gilt market Czech, Huang, Lou and Wang (2021) show that some customers' order flows carry information on future returns. We complement this finding by showing that in the interdealer Bund market order flows via both the exchange and brokers predict future returns, reflecting the informedness of these flows. While our analysis is focused on the D2D segment we also show that there is significant pass-through of OTC discount from the D2D to the dealer-to-customer (D2C) market segment.

The remainder of this paper proceeds as follows. Section 2 describes the Bund market and our dataset. Section 3 introduces our main quantity of interest, OTC discount. In Section 4 we relate OTC discount to search-and-bargaining and information frictions across trading protocols. Section 5 concludes.

2 The Bund Market

2.1 Market Structure

German sovereign debt securities enjoy benchmark status in the euro area and worldwide as a liquid and safe asset. Secondary market trading occurs among dealers and between dealers and customers. We refer to these as the interdealer (D2D) segment and the dealer-to-customer (D2C) segment of the market, respectively. In this paper we focus on the D2D segment which features a hybrid market structure with three distinct trading protocols: bilateral, via a broker, or on the interdealer exchange MTS.

In the bilateral protocol, dealers trade directly with one another in over-the-counter negotiations. These bilateral trades are not observed by other market participants. Dealers can also trade with one another via interdealer brokers. In this case, the initiating dealer communicates the trade request to a broker, who then undertakes to find a suitable counterparty and earns a fee. Crucially, brokers act on a matched principal basis and do not take inventory. Moreover, the involved dealers are unaware of the identity of the counterparty.[2] Broker trades are also unobserved by other market participants.[3]

The third option for Bund dealers to trade with each other is via an exchange. The only platform with a significant market share is the MTS interdealer exchange, which is operated as a fully electronic limit order book market. Dealers actively quote executable

[2]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/, and Appendix A for institutional background on interdealer brokers.

[3]The MiFID II/MiFIR regulation that came into effect in January 2018, after the end of our sample period, introduced provisions for post-trade transparency.

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 2.5 million EUR. Unlike bilateral and broker-facilitated OTC trades, all trading activity on the exchange is observed by all market participants. Subscription services such as Bloomberg allow access to MTS prices and volumes at the best bid and ask levels in real time, even for non-MTS dealers. In what follows, we refer to bilateral and broker trades jointly as *OTC trades*, in contrast to exchange trades on MTS.[4]

This hybrid structure is not unique to the interdealer Bund market but is similar to that of other European sovereign bond markets such as those for sovereign debt issued by France and the UK. In the U.S. Treasury market (Fleming, 1997; Fleming and Remolona, 1999; Mizrach and Neely, 2009), the order book of the BrokerTec platform assumes a role similar to that of MTS in the euro area.

2.2 Data

We focus on German sovereign bonds with maturities of two, five, 10, and 30 years which we jointly refer to as *Bunds*. Reissuances are common for Bunds and on-the-run effects are much less important than for U.S. Treasuries. We therefore include both on-the-run and off-the-run bonds in our analysis.

Our study is based on a unique regulatory transactions dataset of all Bund trades involving at least one German financial institution from June 2011 to December 2017. Importantly, this trade repository includes bilateral D2C trades between German dealers and their customers as well as D2D trades from all three market segments. The transactions data are based on reporting requirements of German financial institutions to the German Federal Financial Supervisory Authority (Bundesanstalt für Finanzdienstleistungsaufsicht, popularly known as "BaFin"). It contains information on the price, size, time, and direction of each trade, as well as a flag indicating whether a trade was over-the-counter or the platform in which the trade was executed. The dataset also includes anonymous

[4]We provide further information on the Bund interdealer market structure in Appendix A.

identifiers for the reporting agent and the counterparty of a trade. We match these data with the full limit order book data from MTS.

[Table 1 about here.]

Table 1 describes the trading activity covered by our sample and the subsamples relevant for our analysis in terms of number of trades, aggregate trading activity, 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, corresponding to a total nominal volume of almost 3.4 trillion EUR (labeled "full sample"). A survey by the German finance agency among Bund Issues Auction Group members pegs daily trading volume in the secondary market at more than 17 billion EUR. Our sample captures about 11% of this trading activity.

For about 210,000 of these trades (corresponding to a volume of roughly 1.5 trillion EUR) we are able to identify both initiator and counterparty (labeled "init. & counterp. ID known" in Table 1).[5] We classify the involved parties as either dealers or customers based on their access to the interdealer exchange MTS. According to this classification we observe about 47,500 interdealer trades between MTS dealers (labeled "D2D"). For trades on its platform, MTS imposes a 2.5 million EUR minimum trade size. To ensure comparability with the OTC segment of the market, we limit our sample to the set of trades above that threshold. These roughly 22,000 interdealer trades (by 34 dealers and via 6 interdealer brokers) represent more than 95% of overall interdealer trading volume. About 2,200 interdealer trades take place on MTS (labeled "D2D via MTS", corresponding to 3.7% of overall observed interdealer volume), while there are about 6,800 OTC transactions resulting from bilateral negotiations ("D2D via bilateral OTC", 18.4% of interdealer volume). The by far largest share of interdealer trading is done via brokers ("D2D via broker (D2B)"), both in terms of number of trades (about 13,300) and overall volume (77.9%).[6] The average nominal trade size in the interdealer segment is

[5]For a detailed description of the dataset and our matching approach please refer to Appendix B.
[6]This figure is in line with evidence provided by Pinter, Wang and Zou (2020) for the UK Gilt interdealer market.

lowest on MTS (7.9 million EUR), somewhat larger (12.7 million EUR) in bilateral OTC transactions, and considerably larger (27.6 million EUR) in broker-intermediated trades.

3 OTC Discount in the Bund Interdealer Market

In this section, we measure the transaction cost of OTC trades relative to those on the exchange protocol of the interdealer Bund market. In doing so we make use of the full limit order book of MTS and compare the transaction costs of OTC trades with the contemporaneous trading conditions on the exchange. Our quantity of interest is the premium or discount that OTC trades pay or receive with respect to bid and ask quotes on MTS when initiating a trade. We define the *OTC discount* as the difference between the price a trade would have incurred on the exchange and the observed price of an OTC trade. We measure OTC discount as a share of the hypothetical transaction cost on the exchange. Formally, OTC discount is defined as:

$$OTC\ discount = \frac{price^{\text{MTS}} - price^{\text{observed, OTC}}}{price^{\text{MTS}} - price^{\text{mid}}}\ , \tag{1}$$

where $price^{\text{MTS}}$ is a reference price that the same trade would have incurred on MTS at the same time.[7] The denominator in Equation (1) is equal to the quoted half-spread on MTS.

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. Trades at the mid-price correspond to 100% OTC discount, the upper bound, whereas buys at the MTS ask price and sells at the MTS bid price have 0% OTC discount, that is, the OTC trade occurred at the same price as on the exchange. When OTC discount is negative, i.e., when it would have been cheaper to trade on MTS instead of OTC, we refer to this as an *OTC premium*.

[7] We infer the initiator of each trade by comparing the trade price to the contemporaneous mid-price on the exchange as in, for example, Bessembinder and Venkataraman (2004). 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).

[Figure 1 about here.]

As the reference price, we choose the quoted price at the respective best level of the limit order book, i.e. $price^{\text{MTS}}$ is the best ask (bid) price for buyer- (seller-) initiated trades. Hence, we disregard that larger trades would also have to execute against quotes at deeper levels of the limit order book (known as "walking up the book"). We do so for several reasons. First, large trades are rare on MTS and the price at the best provides a better benchmark for OTC trades than an "effective" price. Second, in choosing the quoted price at the best as $price^{\text{MTS}}$ our measurement for OTC discount is conservative (i.e. smaller) with respect to a price that takes into account the depth of the order book.

Given that the market share of exchange transactions is substantially lower than that of OTC trading, one might worry about the use of exchange quotes as a reference. However, market share is endogenous to trading conditions and, all else equal, dealers will generally gravitate to cheaper protocols. A better indicator of the potential capacity of the exchange to facilitate trading is the depth of the order book. We find that 98% of all OTC transactions could take place on the MTS order book at the moment of the trade. Moreover, notwithstanding the smaller market share, all limit orders on MTS are executable. MTS bid and ask quotes are thus an appropriate reference price.

[Table 2 about here.]

Table 2 shows the descriptive statistics of OTC discount for the same subsamples of OTC trades as those discussed above. Both mean and median of OTC discount are positive across all considered subsamples, and we reject the null hypothesis that the average OTC discount is zero at the 0.01% significance level using a simple t-test. For interdealer trades with a size of at least 2.5 million EUR the average OTC discount equals 34.7%. This implies that dealers pay on average just about two thirds of the quoted MTS bid-ask spread when trading among each other over-the-counter. The median OTC discount is even larger at 61.6% and the trade at the 95th percentile receives a discount of 96%, implying a trade price just above (below) the MTS mid for buys (sells). Fewer than 16% of trades incur an OTC premium.

These numbers mask sizable differences in the distribution of OTC discount between bilateral and broker OTC trades, however. Bilateral OTC trades receive a considerably larger average discount of 54.6% as opposed to 24.6% for brokered trades. Bilateral trades also have a lower share of trades with an OTC premium: 6.9% compared to 20.4% for trades via brokers. Figure 2 shows the histogram of OTC discount for interdealer trades with a minimum size of at least 2.5 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 heavily tilted towards positive values of OTC discount. Hence, in the majority of cases, trading over-the-counter is cheaper than on the exchange. While the distribution for bilateral trades is more right-skewed, broker trades have a wider distribution and feature OTC premia or trades exactly at the MTS best more often.

[Figure 2 about here.]

The difference in trading cost between bilateral and exchange trades is not only highly statistically significant but also economically meaningful. A simple back-of-the-envelope calculation suggests that an OTC discount of about 30% with respect to the average half bid-ask spread of four basis points on MTS with a daily trading volume of about 17 billion EUR implies a daily cost advantage of about 2 million EUR (500 million EUR annually) from trading OTC rather than on the exchange.

In Appendix C, we show that these results are robust with respect to alternative definitions of OTC discount. First, we explicitly account for the effects of large trades walking up the book, i.e. $price^{\mathrm{MTS}}$ 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. Second, in order to relate to yields instead of transaction 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 $price^{\mathrm{mid}}$. Both alternative definitions equally give rise to pervasive and economically large OTC discount. Furthermore we show in Appendix D that D2C trades also feature a similarly large OTC discount.

4 Drivers of OTC Discount

The results documented in the previous section give rise to two main questions. First, why do dealers prefer to trade OTC – and predominantly so in the broker-intermediated segment – rather than on the exchange? Second, why do we observe an OTC discount, and why is it different across and within OTC protocols?

To answer these questions, we assess the quantitative importance of information and search-and-bargaining frictions in driving the differences in OTC discount across trades. We start by discussing our regression setup. We then present our measurement of the relevant frictions. Next, we present four sets of empirical evidence. First, we assess the drivers of dealers' choice of trading protocol. Second, we investigate whether information and search-and-bargaining frictions can explain the transaction-level variation of OTC discount *within* each protocol. Third, we quantify the difference in OTC discount *across* OTC trade protocols. Finally, we evaluate the information content of protocols' order flows.

4.1 Regression Specification

The OTC discount received by a dealer will influence her decision where to trade. Therefore, trading venue and OTC discount are likely to be determined jointly. To correct for this potential endogeneity, we follow the standard approach of using a two-stage switching model (Madhavan and Cheng, 1997; Bessembinder and Venkataraman, 2004; Hendershott and Madhavan, 2015). The first stage consists of estimating a model of venue choice. The second stage relates the transaction cost variable (here OTC discount) to the explanatory variables and the inverse Mill's ratio calculated from the first stage estimation to control for venue choice.

In the interdealer Bund market dealers face the choice between three trading protocols: exchange, bilateral, or via a broker. We model this choice as a sequential decision. First, we consider the choice between trading on the exchange or OTC. We consider the decision of whether to trade on the exchange first, since execution there is certain and immediate.

If a trade is not executed on the exchange, we next study the decision to trade bilaterally or via a broker.[8] In order to study dealers' decision whether to trade on MTS or OTC, we estimate a probit model where the dependent variable OTC equals one for over-the-counter trades and zero for trades on MTS. Formally, we estimate

$$Pr(OTC_n|\omega_{I,n}) = \Phi(\gamma_I' \omega_{I,n}) \tag{2}$$

at the level of individual trades indexed by n, where Φ is the standard normal cumulative distribution function and $\omega_{I,n}$ is a vector of proxies for search-and-bargaining and information frictions as well as control variables. Conditional on a trade not being executed on the exchange, we estimate a second probit model

$$Pr(Broker_n|OTC_n, \omega_{II,n}) = \Phi(\gamma_{II}' \omega_{II,n}), \tag{3}$$

where the dependent variable $Broker$ equals one for trades via a broker and zero otherwise (i.e., bilaterally negotiated OTC transactions).

In the second stage, we study the factors driving OTC discount in interdealer OTC transactions while controlling for protocol choice. Assuming that error terms are jointly normal, we estimate the following equation separately for bilateral and broker OTC trades at the level of individual trades:

$$OTC\ discount_n = \beta_v' v_n + \beta_{\mathrm{OTC}} \hat{\lambda}_n^{\mathrm{OTC}} + \beta_s \hat{\lambda}_n^s + \varepsilon_n, \tag{4}$$

where $s \in \{\text{bilateral}, \text{broker}\}$ indicates the trading protocol used, individual trades are indexed by n, and v is a vector collecting information and search-and-bargaining frictions as well as control variables. As selectivity adjustments we include the inverse Mill's ratio $\hat{\lambda}^{\mathrm{OTC}}$ to control for the decision to trade over-the-counter, and $\hat{\lambda}^{\mathrm{bilateral}}$ or $\hat{\lambda}^{\mathrm{broker}}$ to control for the decision to trade bilaterally or via a broker, respectively.

[8] In Appendix E, we consider a multinomial logit model for robustness which yields very similar results.

4.2 Measuring Information and Search-and-Bargaining Frictions

We now motivate our choice of regressors to capture the potential drivers of OTC discount and protocol choice. Variable definitions take the point of view of the trader initiating the transaction.

Information frictions. Information-based theories of hybrid markets typically distinguish between uninformed (liquidity-motivated) and informed traders (e.g., Seppi, 1990; Lee and Wang, 2017). Dealers adjust their quotes and limit orders to the perceived informedness of trades. We identify trades with larger price impact as being more informed and measure *Price impact* as the price change 15 minutes after each trade, following Collin-Dufresne et al. (2020). We expect a lower OTC discount for trades with a higher price impact.

In Seppi (1990), equilibria emerge where liquidity traders prefer to trade large blocks over-the-counter, whereas informed traders may also split up an order into a series of smaller trades. We create a dummy variable *Order Splitting* that takes the value of one when a trade is the result of order splitting and zero otherwise. We identify order splitting when a dealer has multiple trades of the same bond in the same direction on a given day. We conjecture a lower OTC discount for trades that are part of order splitting strategies.

Information is often revealed via order flow. Czech et al. (2021) show that the order flow by hedge funds and mutual funds predicts bond returns in the UK Gilt market, and Ranaldo and Somogyi (2021) present similar findings for the FX market. These results are consistent with Grossman (1992) where information need not necessarily be about fundamental value but can also refer to expressed and unexpressed order flow. We use two proxy variables that capture the net order flow of the market: the *Aggregate Order Flow* and the *Order Book Imbalance*. *Aggregate Order Flow* captures for each trade the net order flow of all preceding OTC trades on the same day, including customer trades, in all Bunds. *Order Book Imbalance* measures the contemporaneous imbalance between the best three levels on both sides of the limit order book of the same Bund. Both variables are defined as positive for trades in the direction of the market. We associate trading in the same direction as the market with a higher degree of informedness and expect a lower OTC discount for such trades.

Search-and-bargaining 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 et al., 2005, 2007; Duffie, 2012). On the exchange, dealers do not face search costs and cannot exercise bargaining power. Since OTC discount is a measure of relative transaction cost, this implies that dealers with greater bargaining power should receive larger OTC discounts when initiating trades.

Dealers' inventory is a key factor in trading and pricing decisions (e.g., Stoll, 1978; Amihud and Mendelson, 1980). Inventory requires balance sheet capacity (Dick-Nielsen and Rossi, 2019; Goldstein and Hotchkiss, 2020; Colliard, Foucault and Hoffmann, 2021). Dealers with large inventory are more likely to be constrained and hence in a worse bargaining position. We measure a dealer's *Inventory* as her net imbalance over all Bunds on the same day prior to the trade, measured as a share of her average daily trading volume. The variable is signed so that it is positive for trades increasing a dealer's net inventory position in absolute value. We expect a lower OTC discount for such trades. Search costs amplify inventory risk on volatile days which reduces dealers' bargaining power. We measure *Volatility* as the intraday price volatility of each bond on MTS and conjecture a lower OTC discount for more volatile bond-days.

Previous studies have identified the dealer network structure and trading relations as important factors for pricing in OTC markets (e.g., Di Maggio, Kermani and Song, 2017; Li and Schürhoff, 2019; Hendershott, Li, Livdan and Schürhoff, 2020). Unfortunately, we only observe trades involving German financial institutions and are thus unable to reconstruct the full network structure of interdealer trades. Therefore, we include dealer-fixed effects to capture differences in centrality and individual bargaining power. As an alternative, we use each dealer's overall trading volume (*Dealer Volume*) as an indirect measure of network centrality (cf. Nikolova, Wang and Wu, 2020). We expect larger dealers to receive a higher OTC discount in trades they initiate.

Duffie et al. (2005) argue that access to outside options increases dealers' bargaining power. In the Bund market dealers have the outside option to trade on the exchange. Since large trades become increasingly expensive on MTS, this outside option diminishes with increasing trade size. Therefore, we expect OTC discount to decrease as trade size increases. We measure *Trade Size* on a logarithmic scale.

Appendix F provides detailed definitions of all proxy variables as well as control variables in Table A.10, and their descriptive statistics in Table A.11.

4.3 Protocol Choice in the Interdealer Segment

In this section, we discuss the determinants of dealers' decision to execute a given trade in either segment of the OTC market or on the exchange. We specify Equation (2) as follows:

$$\begin{aligned}\gamma_I' \omega_{I,n} = \gamma_0 &+ \gamma_1 \text{Order Splitting}_n + \gamma_2 \text{Aggregate Order Flow}_n + \gamma_3 \text{Order Book Imbalance}_n \\ &+ \gamma_4 \text{Inventory}_n + \gamma_5 \text{Volatility}_n + \gamma_6 \text{Dealer Volume}_n \\ &+ \gamma_7 \text{Trade Size 10-30 million EUR}_n + \gamma_8 \text{Trade Size} > 30 \text{ million EUR}_n \\ &+ \gamma_9 \text{Round Trade Size}_n + \gamma_C \text{Controls}_n.\end{aligned} \tag{5}$$

Note that $\omega_{I,n}$ includes proxy variables for information and search-and-bargaining frictions detailed in Section 4.2. To account for potential nonlinearities with respect to trade size, we employ dummy variables for trades of $10 - 30$ million EUR and for trades larger than 30 million EUR. The baseline hence consists of trades for $2.5 - 10$ million EUR. In addition *Round Trade Size* is a dummy variable that equals one for trades with a nominal amount of exactly 2.5, 5, or 10 million EUR, typical trade sizes on MTS, and zero otherwise. *Controls* is a vector of further control variables that capture bond-specific liquidity and bond characteristics.[9] Throughout our analysis, all regressors except for dummy variables have been standardized to have mean zero and unit variance.

[Table 3 about here.]

Exchange versus OTC. Column (1) of Table 3 shows the marginal effects of the probit estimation of Equation (2), with standard errors clustered at the dealer level. The following results are noteworthy. First, transactions that have been split into smaller trades are 2.2 percentage points more likely to trade on MTS. This suggests that more informed transactions are more likely to be routed via the exchange. Second, on more volatile days trading on the exchange is more likely. A one-standard deviation increase in volatility increases the likelihood of routing a trade to the exchange by 3.3 percentage points, in line with the notion that the outside option of search in the OTC market is less feasible. Third, over-the-counter trading is preferred when dealers have larger inventories. This effect is statistically significant but small. Fourth, larger trades are less likely to be routed to the exchange. This reflects that in a limit order book transaction costs increase with trade size. Trades in the 10-30 million EUR range are 2.6 percentage points more likely to be traded over-the-counter, with respect to the baseline of trades for $2.5 - 10$ million EUR. This effect is even more pronounced for trades larger than 30 million EUR, where OTC trading is about 10.5 percentage points more likely. The latter three results suggest that search-and-bargaining also plays a role in the choice to trade on the exchange or OTC.

Broker versus Bilateral OTC. More than 75% of interdealer trading is done via brokers. We now discuss the determinants of trading via a broker instead of bilateral negotiations. We estimate the probit model in Equation (3), where the explanatory

[9] The vector includes *MTS half-spread* (half the MTS bid-ask spread), *Depth at MTS best* (logarithm of the volume available at the best), and a dummy variable that equals one for bonds that are *Cheapest-to-deliver* for currently active futures contracts. *2-year Schatz*, *5-year Bobl*, and *30-year Bund* are dummy variables that indicate a maturity at issuance of 2, 5, or 30 years, respectively. Further control variables account for issuance days (dummy), (logarithmic) amount outstanding, bond age (as a percentage of original maturity), the coupon rate (in percent), end-of-quarter effects (dummy) and end-of-year effects (dummy), on-the-run status (dummy), and whether the dealer is a German financial institution (dummy).

variables and controls are the same as in Equation (5), with the exception of the dummy for *Round Trade Size* which is no longer relevant. Column (2) of Table 3 shows the marginal effects of the probit estimation.

We highlight the following results. First, more informed transactions are more likely to be intermediated by a broker than bilaterally negotiated: transactions that have been split into smaller trades are almost three percentage points more likely to be routed via a broker. Second, dealers with larger inventories are more likely to trade via brokers. A one-standard deviation increase in dealer inventory increases the likelihood of broker intermediation by more than two percentage points. Third, large dealers are more likely to trade via brokers than smaller ones. Fourth, larger trades are significantly more likely to be routed via brokers. OTC trades in the $10-30$ million EUR range are more than 20 percentage points more likely to be broker-intermediated. Trades larger than 30 million EUR are almost 40 percentage points more likely to be routed via a broker. The latter three findings can be interpreted as larger and thus arguably more central dealers and dealers with larger trading needs avoiding to trade with one another bilaterally, preferring instead to conceal their transactions from each other by trading via brokers, for example to maintain their informational advantage (Holland, 2001; Babus and Kondor, 2018) or to protect themselves against frontrunning (Harris, 1997; Brunnermeier and Pedersen, 2005).[10]

In sum, our results regarding the choice between OTC and exchange suggest that more informed transactions are more likely to take place on the exchange. Similarly, among OTC trades more informed transactions are more likely to be routed via an interdealer broker. Combined, this points to a role for information frictions in dealers' trading decisions.

4.4 Determinants of OTC Discount within OTC Protocols

What explains the variation in OTC discount across transactions *within* the same trading protocol? To answer this question, we estimate Equation (4) at the level of

[10] In line with the first motive e.g., Hagströmer and Menkveld (2019) find that strongly connected central FX dealers are more informed.

individual trades and separately for bilateral and broker-facilitated OTC trades. In addition to the selectivity adjustments, the explanatory variables in Equation (4) are

$$\begin{aligned}\beta_v' v_n = \ & \beta_0 + \beta_1 \text{Price Impact}_n + \beta_2 \text{Order Splitting}_n \\ & + \beta_3 \text{Aggregate Order Flow}_n + \beta_4 \text{Order Book Imbalance}_n \\ & + \beta_5 \text{Inventory}_n + \beta_6 \text{Volatility}_n + \beta_7 \text{Trade Size (log)}_n \\ & + \beta_b \Delta_b + \beta_i \Delta_i + \beta_C \text{Controls}_n \ ,\end{aligned} \tag{6}$$

where Δ_b and Δ_i are bond- and initiating dealer fixed effects, respectively, and *Controls* is a vector accounting for MTS half-spread, depth at the MTS best, issuance days, cheapest-to-deliver and on-the-run status, bond age and end-of-quarter and end-of-year effects. Table 4 shows the estimation results, with standard errors obtained via bootstrap to account for correlation with protocol choice.[11]

[Table 4 about here.]

Bilaterally Negotiated Interdealer Trading. Column (1) of Table 4 reports the estimations for the OTC discount of bilaterally negotiated OTC trades between MTS dealers. We first analyze the role of information frictions in driving OTC discount. A one-standard deviation increase in price impact corresponds to a 1.9 percentage points lower OTC discount.[12] Trades that are part of an order splitting strategy receive a 5.0 percentage points lower discount. Moreover, the coefficient for aggregate order flow is negative, meaning that trading in the same direction as the overall market lowers OTC discount. In combination, these results suggest that dealers price discriminate against one another based on their counterparty's perceived informedness, in line with theories of information frictions.

[11] Specifically, we draw 1,000 samples of the same number of trades with replacement from our set of trades. For each sample we repeat the protocol choice and OTC discount estimations, and obtain standard errors from the distribution of coefficient estimates. We deem very large OTC premia as unrealistic and winsorize OTC discount from below at -100%. Our results are robust to omitting this cleaning step.

[12] We have verified that our results do not materially change 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.

We now turn to the role of search-and-bargaining frictions as drivers of OTC discount. A higher dealer inventory in a specific security is associated with a lower OTC discount, consistent with reduced bargaining power. Volatility, which makes the outside option of continued search more costly or less feasible, also compresses OTC discount. This effect is significant and sizeable, with a one-standard deviation increase in volatility reducing OTC discount by 10 percentage points. The OTC discount decreases with trade size. A trade that is larger by one standard deviation would receive an OTC discount that is 4.8 percentage points lower. This is consistent with the notion that the exchange is a less feasible outside option for large trades, thus weakening the bargaining position.[13]

In addition to trade-specific measures of bargaining power, the individual bargaining power of different dealers can be assessed by comparing dealer fixed effects. Since we control for a host of other confounding effects, differences in the fixed effects should to a large extent reflect dealers' differential bargaining power. Dealer fixed effects differ markedly: in the estimation we performed in column (1) of Table 4 the standard deviation of the fixed effect across dealers amounts to 17.6 percentage points of the MTS half-spread – almost one third of the average OTC discount. We interpret this dispersion of dealer fixed effects as representing significant heterogeneity in dealers' bargaining power.

To further illustrate the effect of dealer-specific bargaining power, we construct dummy variables for the top and bottom five dealers in terms of their dealer fixed effects in column (1) of Table 4. In column (2) we repeat the estimation including these dummies instead of dealer-fixed effects. The top five dealers receive an 8.5 percentage points higher OTC discount than their peers, whereas the bottom five receive a 35.4 percentage points lower OTC discount. These effects are sizeable given that the average OTC discount is 54.6 percentage points. This suggests that dealer-specific bargaining power plays a quantitatively important role for OTC discount, over and above the proxies included in our regressions.

[13]While in pure OTC markets transaction costs typically decrease with trade size (Edwards et al., 2007; Green, Hollifield and Schürhoff, 2007; O'Hara and Zhou, 2021), Pintér, Wang and Zou (2021) show that after controlling for trader identities costs increase with size, in line with our setup and result.

We show the robustness of our results in Appendix C. We consider alternative definitions of OTC discount, where we a) normalize OTC discount by price instead of transaction cost and b) include the effect of larger trades walking up the limit order book and consuming liquidity from deeper levels of the limit order book. All results are quantitatively and qualitatively in line with those presented here.

Broker-Intermediated Interdealer Trading. We now investigate whether we observe similar drivers of OTC Discount for trades intermediated by interdealer brokers. Column (3) in Table 4 shows the estimation results for interdealer trades routed via brokers. We again begin by discussing the importance of information frictions. We find that higher price impact and the presence of order splitting both correspond to lower discounts. While the coefficient on order splitting is similar to bilateral trades, it is almost 50% lower for price impact. Trading in the same direction as the market also significantly lowers OTC discount. A one-standard deviation higher aggregate order flow implies a 2.6 percentage points lower OTC discount for broker-facilitated trades, compared to less than one percentage point for bilateral trades.

Turning to measures of search-and-bargaining frictions, the estimation coefficient for inventory is a bit smaller than for bilateral trades but not statistically significant. As before, days with higher volatility are characterized by lower OTC discounts. The impact of volatility is 50% larger than for bilateral trades and highly statistically significant. A one-standard deviation larger trade is associated with a 3.4 percentage points lower OTC discount. This is somewhat lower than for bilateral trades but still sizeable. Combined, these results show that more informed trades receive lower OTC discounts, in line with information-based theories of hybrid markets. At the same time, we find that less bargaining power translates into lower OTC discount, consistent with search-based theories of OTC markets.

In general, the estimated coefficients have the same sign as for bilateral and broker-intermediated trades, but they vary somewhat in magnitude.

4.5 Difference in OTC Discount across OTC Protocols

We now turn our attention to the difference in OTC discount across the two OTC trading protocols. Table 2 reveals a sizable difference in the unconditional average OTC discount of bilateral and broker-intermediated OTC trades. Even accounting for the various information and search-and-bargaining frictions in the previous section, not all differences in OTC discount can be explained.[14] This is surprising in light of the fact that 78% of the transaction volume in the D2D segment is routed via brokers. We therefore corroborate this finding with two alternative approaches.

First, we use the coefficients of Equation (4) for the drivers of OTC discount (specifications (1) and (3) in Table 4) to construct a predictor for OTC discount given trade characteristics. That is, we compute for each bilaterally negotiated trade the predicted OTC discount it would have received had it been intermediated via a broker. Similarly, we compute the predicted OTC discount the broker-intermediated trades in our sample would have received had they been bilaterally negotiated. We then calculate the difference between the hypothetical predicted OTC discount using one protocol and the observed OTC discount using the other protocol for each trade. The average of this difference is 18.9 percentage points and statistically significant at the 1% level.

Second, we consider similar trades that were carried out via different trading protocols. Specifically, we construct a matched sample that pairs bilaterally negotiated trades with similar broker transactions using nearest neighbor propensity score matching.[15] We then estimate the following equation:

$$OTC\ discount_n = \beta' v_n + \varepsilon_n\,. \tag{7}$$

[14]This can be seen in the estimated intercepts in columns (1) and (3) of Table 4. The difference between the two intercepts shows that broker-intermediated trades feature an OTC discount that is on average 22.5 percentage points lower than for bilateral trades.

[15]The variables used in the matching procedure are the MTS bid-ask spread and depth, (logarithmic) trade size, the date, bond identifier, the identity of the initiating dealer, the direction of the trade, volatility, inventory, order flow, 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 dimensions; that is, we allow only for perfect matches of trades from the same dealer in the same security. 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 dealer's full trading activity.

Since our sample by construction consists of similar trades, there are no selectivity corrections as in Equation (4). In addition to the variables used above, v now also contains a dummy variable indicating trades via brokers.

[Table 5 about here.]

Table 5 shows the results. The main finding is that broker-facilitated trades have an OTC discount that is about 15 percentage points lower than bilaterally negotiated trades in the matched sample. While this is a bit smaller than the difference obtained above, it highlights that broker trades receive a substantially lower OTC discount than bilaterally negotiated trades. Compared to the average OTC discount of 55% for bilateral interdealer trades reported in Table 2, broker trades are about $27-34\%$ more expensive.

4.6 Information Content of Order Flows

Our analysis has established a pecking order of transaction costs in the Bund market. Trades on the exchange are more expensive than OTC trades. Moreover, bilateral trades have lower transaction costs than broker-intermediated OTC trades. Neither of these findings can be explained by theories emphasizing the role of search-and-bargaining frictions in OTC markets. First, if such frictions were the main driver of transaction costs, then the exchange protocol, where they are absent, should be the cheapest. Second, as search costs are arguably lower for broker-intermediated than bilateral OTC trades, they should feature a higher, not a lower, discount.

Both of these findings can be explained by information motives. Liquidity providers on the exchange might charge a wider spread to protect themselves from being adversely selected by more informed traders. Similarly, dealers providing liquidity via brokers may request wider spreads since the broker protocol conceals the identity of the counterparty, who may be more informed.

To the extent that there are systematic differences in informational content, they should be reflected in the order flow coming from each protocol. Informed trading is often associated with realized returns. We follow the literature on informed trading in bond markets (Czech et al., 2021) to assess whether the information content of trades can explain the pecking order of transaction costs that we have documented. Specifically, we regress bond returns on order flows in each protocol as follows:

$$
\begin{aligned}
\textit{return}_{i,d,d+\Delta} = \; & \gamma_0 + \gamma_1 \text{MTS order flow}_{i,d} + \gamma_2 \text{Broker order flow}_{i,d} \\
& + \gamma_3 \text{Bilateral order flow}_{i,d} \\
& + \gamma_d \Delta_d + \gamma_i \Delta_i + \gamma_C \text{Controls}_n + \varepsilon_{i,d} \,.
\end{aligned} \tag{8}
$$

Here, $\textit{return}_{i,d,d+\Delta}$ denotes the cumulative log return of bond i from day d to day $d+\Delta$ in basis points. MTS order $\text{flow}_{i,d}$, Broker order $\text{flow}_{i,d}$, and Bilateral order $\text{flow}_{i,d}$ are computed for each bond and trading day and standardized to have unit variance.[16] Control variables include the customer order flows, lagged return, the logarithm of the amount outstanding in the bond, and the logarithm of the remaining maturity. Furthermore, we include bond and day fixed effects.

[Table 6 about here.]

Table 6 shows the results of this regression for horizons Δ of 1, 2, and 5 days ahead. We see that order flow via the exchange is statistically significant for the 2- and 5-day horizons and has the strongest price impact at all horizons. While the coefficient on order flow via brokers is slightly smaller, it is statistically significant at the 5% level for the two-day horizon. By contrast, bilateral order flow is indistinguishable from zero at all horizons.

These findings are consistent with our results from the estimation of protocol choice in Section 4.3. More informed transactions are more likely routed to the exchange, and among OTC transactions broker-intermediated trades seem to have greater information content than bilateral trades. Both sets of results from protocol choice at the transaction level and the information content of order flows are in line with the pecking order for OTC discount

[16] We trim returns at the 1st and 99th percentile. For a bond without any trades in a given day, the corresponding order flow is set to zero (before standardizing).

we have documented above. Thus information frictions represent a coherent explanation for the unconditional differences in transaction costs across interdealer protocols.

4.7 The Dealer-to-Customer Segment

While our paper focuses on the hybrid market structure of the Bund interdealer segment and their main drivers, an interesting complementary question is how this structure and dealers' pricing and trading decisions in the interdealer segment affect trading conditions in the dealer-to-customer segment. In Appendix D, we extend our analysis to the D2C segment of the Bund market and present three main findings. First, we observe an OTC discount with respect to MTS quotes even for D2C trades, suggesting that dealers pass on a substantial share of their trading advantage to their clients. Second, information and search-and-bargaining frictions play a similar role in driving OTC discount as in the D2D segment. Third, dealers with more bargaining power in the interdealer segment offer lower transaction costs to their clients.

5 Conclusion

In an environment where academics and regulators increasingly call for a shift from traditional over-the-counter market structures toward electronic platforms and greater transparency, understanding the drivers of dealers' pricing decisions across trading protocols is ever more important. This paper contributes to this understanding along several dimensions. Using a unique regulatory dataset of securities transactions, we find that the vast majority of OTC trades execute at favorable prices relative to the exchange limit order book. This OTC discount is significantly larger for bilateral than for broker-intermediated OTC trades. We document that this pecking order of transaction costs is consistent with the relative informedness of order flows from the different protocols. Moreover, we show that the variation of OTC discount across transactions within the same protocol is driven by both information and search-and-bargaining frictions, suggesting that both types of frictions are relevant for the modelling of hybrid markets.

These results are relevant for the current regulatory debate. 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 of improving market conditions in and beyond European markets and in the U.S., where FINRA has started to collect data similar to that in the TRACE database also for sovereign bonds. As pointed out by Dugast, Üslü and Weill (2019), even if a centralized exchange market is socially optimal, agents' decisions for trading protocols are driven by their private incentives. While our empirical analysis cannot shed light on the socially optimal market structure, our results suggest that OTC, exchange, and 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.

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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. For a buyer-initiated trade *OTC discount* is the price difference between the quoted best ask price on MTS and the observed price of the trade, measured as a share of the MTS half-spread, that is, the difference between the best ask and the mid price. For a seller-initiated trade *OTC discount* is, symmetrically, the normalized difference between the observed price of the trade and the quoted best bid. 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, that is, 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, that is, the OTC trade presented no price improvement over MTS.

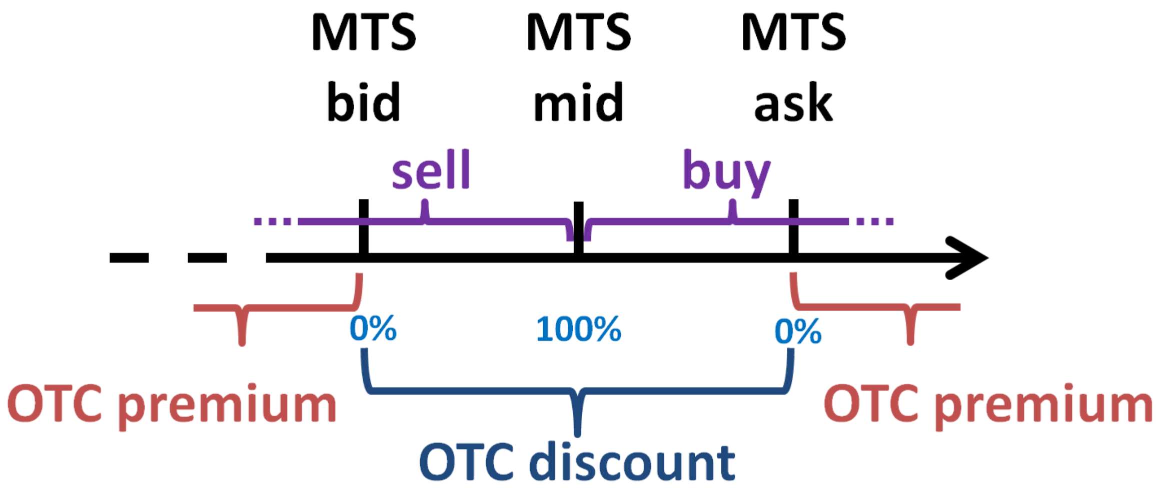
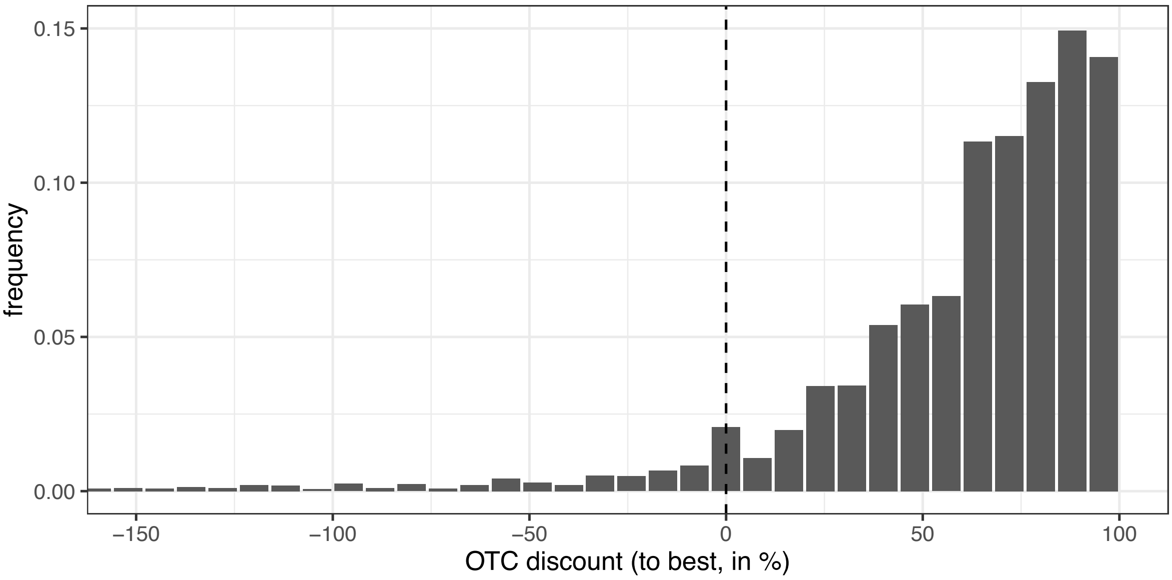
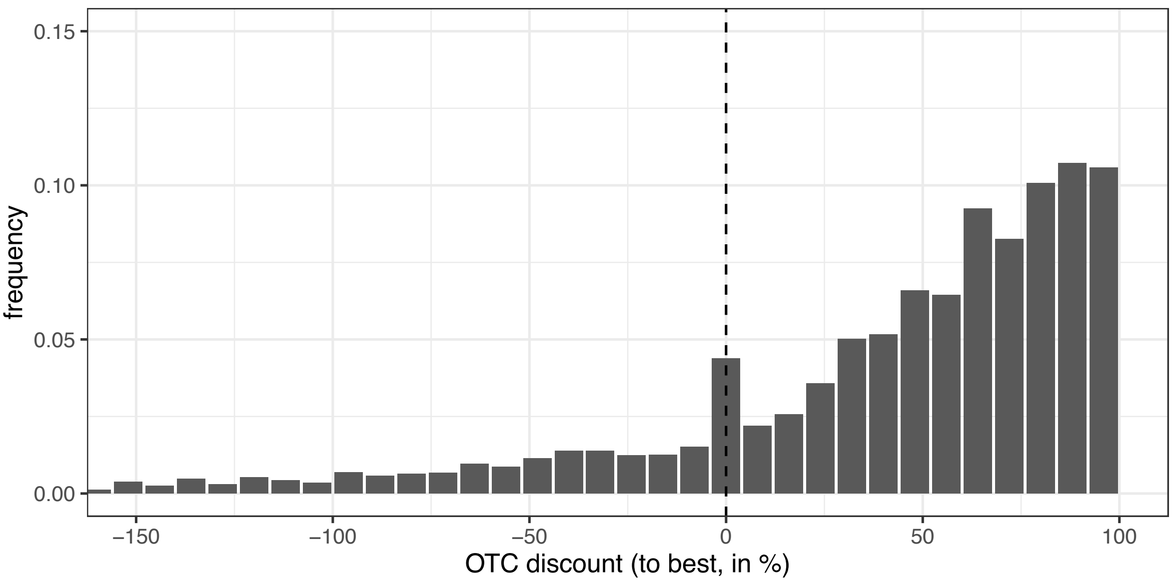


Figure 2. Histogram of OTC Discount: *OTC discount*, defined in Equation (1) in Section 3, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, measured as a share of the MTS half-spread. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. OTC discount is bounded from above to be 100%, at most. The figure shows the distribution of OTC discount based on interdealer trades of nominal size of at least 2.5 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 Bunds involving German financial institutions from June 2011 through December 2017.



(a) Interdealer trades via bilateral OTC.



(b) Interdealer trades via broker.

Tables

Table 1. 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, and *init. & counterp. ID known* to those trades where both parties are identified. In the interdealer segment (labeled *D2D*) we consider the subset of all trades with a nominal amount of at least 2.5 million EUR (*trade size* $\geq$ *2.5 million EUR*) and distinguish by trading protocol: *D2D via MTS*, i.e. trades on the interdealer exchange MTS, *D2D via bilateral OTC*, i.e. bilaterally negotiated interdealer trades, 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 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	503,220	3,395.39		6.75	19.46	0.00	0.10	1.00	5.00	30.00
init. & counterp. ID known	211,886	1,485.02		7.01	17.35	0.01	0.18	1.25	5.00	32.50
D2D	47,449	493.55		10.40	19.95	0.10	0.90	2.00	10.00	50.00
trade size $\geq$ 2.5 million EUR	22,252	470.13	100.00	21.13	25.13	2.75	5.00	10.00	25.00	72.00
D2D via MTS	2,179	17.18	3.65	7.88	6.40	2.50	5.00	5.00	10.00	13.00
D2D via bilateral OTC	6,791	86.52	18.40	12.74	20.30	2.60	3.80	5.40	11.60	50.00
D2D via broker (D2B)	13,282	366.43	77.94	27.59	27.09	3.00	7.00	20.00	40.00	85.00

Table 2. Descriptive Statistics of OTC Discount: *OTC discount*, defined in Equation (1) in Section 3, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, measured as a share of the MTS half-spread. It is given in percentage 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 1, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. For the calculation of mean and standard deviation we winsorize OTC discount for each subsample at the 0.5th and 99.5th percentiles. The column *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent and p-value refers to a t-test of the mean being different from zero. Based on regulatory data of all transactions in Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,018	35.85	105.89	-109.50	32.00	65.71	84.00	96.23	13.5	0.0000
init. & counterp. ID known	209,427	45.91	72.69	-74.39	36.67	66.67	85.00	96.47	11.3	0.0000
D2D	45,032	39.97	82.05	-100.00	32.00	65.33	84.00	96.25	13.2	0.0000
trade size $\geq$ 2.5 million EUR	20,073	34.71	87.29	-125.25	25.00	61.60	82.35	96.00	15.8	0.0000
D2D via bilateral OTC	6,708	54.57	60.44	-25.00	45.71	70.00	85.71	96.00	6.9	0.0000
D2D via broker (D2B)	13,226	24.60	96.44	-160.47	9.52	55.50	80.00	95.65	20.4	0.0000

Table 3. Probability Model for Protocol Choice: Marginal effects at means of a probit model. In specification (1) we estimate $Pr(OTC_n|\omega_n) = \Phi(\gamma'\omega_n)$, where OTC_n is a dummy variable that takes the value of one when the trade protocol for transaction n is either bilaterally negotiated or broker intermediated, and zero when it is MTS. In specification (2) we estimate $Pr(Broker_n|OTC_n, \omega_n) = \Phi(\gamma'\omega_n)$, where $Broker_n$ is a dummy variable that takes the value of one when the trade protocol for transaction n is broker intermediated, and zero when it is bilaterally negotiated. Φ is the standard normal cumulative distribution function and ω_n is a vector of variables representing search-and-bargaining and information frictions as detailed in Equation (5), cf. section 4.3. Control variables include: MTS half-spread, depth at the MTS best, dummy variable for cheapest-to-deliver securities, dummy variable for securities with on-the-run status, bond age, coupon rate, maturity at issuance, amount outstanding, dummy variable for issuance days, and dummy variable for end-of-quarter days or end-of-year days. The sample consists of interdealer trades for a minimum trade size of 2.5 million EUR (rows *D2D via MTS*, *D2D via bilateral OTC*, and *D2D via broker (D2B)* in Table 1 for specification (1) and rows *D2D via bilateral OTC*, and *D2D via broker (D2B)* for specification (2)). Based on regulatory data including all transactions in Bunds involving German financial institutions from June 2011 through December 2017. Z-scores are given in parentheses where standard errors are clustered at the dealer level, and *, **, and *** denote significance at the 10%, 5%, and 1% level respectively.

Interdealer trades:	OTC vs. MTS	broker vs. bilat. | OTC
	(1)	(2)
Order splitting (dummy)	-0.0222***	0.0285*
	(-3.6799)	(1.8812)
Aggregate order flow	0.0040	0.0089*
	(1.5018)	(1.7788)
Order book imbalance	0.0033*	-0.0052*
	(1.9525)	(-1.8762)
Inventory	0.0081***	0.0228***
	(3.0708)	(3.1592)
Volatility	-0.0330***	-0.0032
	(-7.4510)	(-0.3299)
Dealer volume	-0.0191	0.1450***
	(-0.9528)	(2.8500)
Trade size 10-30 million EUR (dummy)	0.0257**	0.2101***
	(2.1798)	(4.1466)
Trade size > 30 million EUR (dummy)	0.1051***	0.3726***
	(4.0545)	(7.7091)
Round trade size (2.5/5/10 mn EUR, dummy)	-0.1696***	
	(-9.6929)	
R^2_{pseudo}	0.4119	0.1863
N	22,234	20,058
Controls	yes	yes

Table 4. Intermediation Frictions and OTC Discount : OLS estimation of $OTC\ discount_n = \beta_v' v_n + \beta_{\text{OTC}} \lambda_n^{\text{OTC}} + \beta_s \lambda_n^s + \varepsilon_n$ (see Equation (4) and Section 4.4). The dependent variable, *OTC discount*, defined in Equation (1) in Section 3, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, measured as a share of the MTS half-spread. v_n, as detailed in Equation (6), is a vector of variables representing search-and-bargaining and information frictions, and containing control variables, including fixed effects for bond and initiating dealer, respectively. λ^{OTC} and λ^{s}, s $\in \{bilateral, broker\}$, are the Inverse Mills ratios controlling for protocol choice. Control variables include: MTS half-spread, depth at the MTS best, dummy variable for issuance days, dummy variable for cheapest-to-deliver securities, dummy variable for securities with on-the-run, bond age, and dummy variable for end-of-quarter days or end-of-year days. The sample consists of bilaterally negotiated OTC trades between dealers in specifications (1) and (2) (row *D2D via bilateral OTC* in Table 1) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker (D2B)* in Table 1). The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data including all transactions in Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are obtained through sampling. t-values are given in parentheses and *, **, and *** denote significance at the 10%, 5%, and 1% level respectively.

Interdealer trading protocol:	bilateral OTC		via broker
	(1)	(2)	(3)
Price impact (15min)	-1.9185***	-1.9026***	-1.1423**
	(-3.2840)	(-3.2431)	(-2.1311)
Order splitting (dummy)	-4.9953***	-5.4758***	-4.4372***
	(-3.5498)	(-4.0014)	(-3.8378)
Aggregate order flow	-0.9463*	-0.9365*	-2.5557***
	(-1.7913)	(-1.8054)	(-5.2418)
Order book imbalance	-0.4116	-0.2875	0.1731
	(-0.8062)	(-0.5641)	(0.3407)
Inventory	-0.9361*	-0.8424*	-0.6178
	(-1.7502)	(-1.7192)	(-1.2251)
Volatility	-10.0055***	-10.2561***	-15.8215***
	(-9.2682)	(-9.5906)	(-14.3852)
Trade size (log)	-4.7626***	-5.9917***	-3.4012***
	(-3.7963)	(-8.0209)	(-3.1705)
Top 5 dealer (dummy)		8.4573***	
		(6.7460)	
Bottom 5 dealer (dummy)		-35.4094***	
		(-3.7729)	
Inv. Mills OTC	-0.5465	-0.4608	0.3814
	(-1.0144)	(-0.8693)	(0.7244)
Inv. Mills bilateral	1.0882	-0.1800	
	(0.7115)	(-0.2207)	
Inv. Mills broker			-6.6742***
			(-4.7556)
Intercept	59.9439***	58.8983***	37.4710***
	(87.5601)	(83.2385)	(46.8268)
R^2	0.1402	0.1277	0.2160
R^2_{adjusted}	0.1185	0.1099	0.2073
R^2_{within}	0.0813	0.0935	0.0794
N	6,578	6,578	12,947
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Table 5. Differences in OTC Discount across Interdealer Protocols: OLS estimation of $OTC\ discount_n = \beta' v_n + \varepsilon_n$ (see Equation (7) and Section 4.5). The dependent variable, *OTC discount*, defined in Equation (1) in Section 3, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, measured as a share of the MTS half-spread. v_n is a vector of trade and bond characteristics. It contains a dummy variable indicating whether an interdealer trade was via a broker, and variables representing search-and-bargaining and information frictions, as well as control variables, including fixed effects for bond and initiating dealer respectively. Control variables include: MTS half-spread, depth at the MTS best, dummy variable for issuance days, dummy variable for cheapest-to-deliver securities, dummy variable for securities with on-the-run, bond age, and dummy variable for end-of-quarter days or end-of-year days. The sample consists of bilateral and broker OTC interdealer trades that are matched along the dimensions of trade size, MTS (half-)spread, date, bond and initiating dealer, among others. Further details of the matching process are described in Section 4.5. The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data of all transactions in 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 parentheses and *, **, and *** denote significance at the 10%, 5%, and 1% level respectively.

	(1)	(2)
Trade via broker (dummy)	-14.9535***	-14.4958***
	(-7.6940)	(-5.8595)
Price impact (15min)		-0.0180
		(-0.0216)
Order splitting (dummy)		-3.8593*
		(-2.3439)
Aggregate order flow		-1.6376*
		(-2.0501)
Order book imbalance		-0.7139
		(-1.1042)
Inventory		-0.2328
		(-0.2569)
Volatility		-5.9699***
		(-4.0894)
Trade size (log)		0.7572
		(0.4755)
R^2	0.0975	0.1352
R^2_{adjusted}	0.0725	0.1079
R^2_{within}	0.0368	0.0770
N	4,194	4,194
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table 6. Bond Returns and Interdealer Order Flows: OLS estimation of $return_{i,d,d+\Delta} = \gamma_1\text{MTS order flow}_{i,d} + \gamma_2\text{Broker order flow}_{i,d} + \gamma_3\text{Bilateral order flow}_{i,d} + \gamma_d\Delta_d + \gamma_i\Delta_i + \gamma_C\text{Controls}_n + \varepsilon_{i,d}$ (see Equation (8) and Section 4.6). The dependent variable $return_{i,d,d+\Delta}$ is the logarithmic return of bond i from end of day d to end of day $d+\Delta$, given in units of basis points and trimmed at the 1st and 99th percentiles. All order flow variables are computed for each bond and trading day and standardized. Control variables include customer order flow, the lagged return (in basis points), the logarithm of the amount outstanding in the bond (standardized), and the logarithm of the remaining maturity (standardized). The sample consists of 2-, 5- and 10-year Bunds from June 2011 through December 2017. Because 30-year Bunds are much less liquid and less often traded than other maturities, we exclude them from this part of our analysis. Order flow variables are based on regulatory data of all transactions in Bunds involving German financial institutions. t-values based on heteroskedasticity-robust standard errors are given in parentheses.

Dependent variable:	$return_{i,d,d+1}$	$return_{i,d,d+2}$	$return_{i,d,d+5}$
	(1)	(2)	(3)
MTS order flow	0.0486	0.1601**	0.1928*
	(1.0749)	(2.4484)	(1.8694)
Broker order flow	0.0352	0.1193**	0.0840
	(0.8374)	(1.9856)	(0.9004)
Bilateral order flow	0.0321	0.0487	-0.0882
	(0.7653)	(0.7941)	(-0.9414)
R^2	0.4848	0.4875	0.4999
R^2_{adjusted}	0.4722	0.4750	0.4877
R^2_{within}	0.0008	0.0011	0.0039
N	73,990	73,925	73,620
Bond FE	yes	yes	yes
Date FE	yes	yes	yes
Controls	yes	yes	yes

Appendix

accompanying

OTC Discount

September 9, 2021

A Microstructure of the Bund Interdealer Market

German government securities are issued as 6- or 12-month zero coupon discount papers ("Unverzinsliche Schatzanweisungen", *Bubills*), 2-year "Bundesschatzanweisungen" (*Schaetze*), 5-year "Bundesobligationen" (*Bobls*) and 10- and 30-year "Bundesanleihen" (*Bunds*). There are also inflation-linked Bobls and Bunds, and since September 2020 so-called "Green" Bunds, which we do not consider in this study. We likewise do not consider any municipal debt, such as *Laender* bonds, or debt securities from supranationals with a federal guarantee, e.g. by Kreditanstalt für Wiederaufbau (KfW).

The federal government securities are issued regularly by the German finance agency ("Deutsche Finanzagentur", *DFA*) either as new issues or as reopenings of already issued bonds.[17] Participants in this primary market are the members of the *Bund Issues Auction Group* which currently includes 36 international banks that commit to subscribing to a certain minimal amount of the total annual issuance. 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.[18]

The availability of MTS data to traders and researchers has given MTS a benchmark function for European sovereign bond markets. The list of MTS participants largely overlaps with the members of the Bund Issues Auction Group.[19] 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. Note that MTS participants must be banks, thus barring, e.g., hedge funds from accessing the trading venue (MacKenzie, Hardie, Rommerskirchen and van der Heide, 2020). Even though provisions for midpoint matching are in place on MTS, the mechanism is only very sporadically used by participants, and we observe no such trades in our sample. Iceberg orders are allowed on MTS, but are also

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

[18]For more details regarding the auction process, auction schedule, members of the Bund Issues Auction Group, and auction results, see `https://www.deutsche-finanzagentur.de/en/institutional-investors/primary-market/`.

[19]The current list of members is available at `www.mtsdata.com/content/data/public/gem/anagraph/member.php`.

rarely used or executed. On the BrokerTec platform for U.S. Treasury bonds size-discovery protocols such as the "work up" described in Duffie and Zhu (2017) and Fleming and Nguyen (2019) are heavily used. On MTS, similar protocols exist but play a negligible role. 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).

Another way for Bund dealers to trade with each other is via interdealer brokers. These intermediaries operate on a "matched principal" basis. That is, brokers survey trading interests and quotes from dealers and to facilitate so may also publish indicative prices. Once the broker has overlapping trading interests the terms and price of the transaction are verified and confirmed. Crucially, the settlement is made between the broker and each involved dealer separately, so that the dealers remain anonymous while the broker takes no own inventory risk.[20] Broker fees are of the order of 0.15 basis points.[21]

There are also 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. 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, with one such bond being the *cheapest-to-deliver*. Its price is thus closely tied to the one of the futures via an arbitrage relationship, and we account for this in our analyis.[22]

[20] Cf. Tradition execution policy, available at `https://www.tradition.com/media/267102/TraditionExecutionPolicy-2018-01.pdf`.

[21] Cf. Tradition rate card for European government bonds, `https://www.tradition.co.uk/media/297675/2018.06.28-Bonds-EGBs.pdf`.

[22] 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 more active futures market, anyone wanting to own Bunds, e.g., for regulatory reasons or to enter an arbitrage position, is active in the cash market.

B Data Matching Process

The German Securities Trading Act ("Wertpapierhandelsgesetz") and its corresponding regulation ("Wertpapierhandel-Meldeverordnung") include regulatory reporting requirements that are the base of our transactions data.[23] Gündüz, Ottonello, Pelizzon, Schneider and Subrahmanyam (2021) provides a description of of the dataset and data cleaning procedures.

Our dataset from the interdealer exchange MTS contains all trades as well as the full limit order book information on all executable quotes. 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.

We use further information on the initiator and counterparty in order to categorize trades. This information may be unavailable, either when a counterparty is not identified in the transactions data (e.g. for counterparties not required to report to the German authorities), or where we cannot identify the trade sign, e.g., for trades at exactly the MTS mid-price or outside of MTS trading hours.[24]

C 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

[23]Non-binding English translations of the legal texts are 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`.

[24]MTS operates from 8:00 a.m. to 5:30 p.m. CET. Quoting and trading activity is low during the first hour. Therefore, we consider only trades from 9:00 a.m. onward.

that such trades automatically incur higher transaction costs and is often referred to as "walking up the book." In practice, traders in limit order markets try to overcome this added cost by splitting larger orders into multiple sequentially executed orders, and by 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 here an alternative specification that considers the effects of walking up the book.

To this end, we re-visit the definition of OTC discount (Equation (1) in Section 3) and we re-define OTC discount to take into account the full state of the limit order book. To this end, $price^{\mathrm{MTS}}$ is no longer the price at the respective best level but takes into account the complete depth of the full limit order book.[25]

[Table A.1 about here.]

Table A.1 provides summary statistics for OTC discount following this new definition. OTC discount increases when including the effect of walking up the book (i.e. comparing to Table 2). This is a mechanical effect due to our updated definition. Since for larger trades the comparison transaction cost on MTS becomes higher, the discount of OTC trades (which remains unchanged) 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 is now 61.6% and 46.6% for interdealer trades via brokers.

[Table A.2 about here.]

Table A.2 presents the results of estimating Equation (4) with OTC discount as defined above as the dependent variable. Most results are similar to those presented in the main text and Table 4. That is, more informed trades receive lower discounts, and OTC

[25]That is, $price^{\mathrm{MTS}}$ is the weighted mean of the price of all limit order levels that would be needed to completely fill the a market order corresponding to the size of the trade, and each limit order price level is weighted by the volume that would have been consumed from the respective level.

discount is also smaller when bargaining power is reduced. The most notable difference with respect to our main specification is for trade size, which now has a positive coefficient and is significant at the 1% level for broker trades. 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.

[Table A.3 about here.]

In Table A.3 we present the results of regressing the alternative definition of OTC discount on the matched sample described in Section 4.5. 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, $11.1 - 12.8$ percentage points less discount than bilateral interdealer trades, with the difference significant at the 1% level. Despite the altered definition of OTC discount, this result is very much in line with the $14.5 - 15.0$ percentage points difference obtained in Section 4.5 and Table 5, 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 as

$$OTC\ discount = \frac{\epsilon \left(price^{\text{MTS}} - price^{\text{observed, OTC}}\right)}{price^{\text{mid,MTS}}}, \tag{9}$$

where $price^{\text{observed, OTC}}$ is the price of an over-the-counter trade observed in our transaction data and $price^{\text{MTS}}$ is the 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. $price^{\text{MTS}}$ is the best ask (bid) price for buyer- (seller-) initiated trades as in our main specification. Crucially, the denominator in Equation (9) 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 about here.]

Table A.4 presents summary statistics for OTC discount measured as a share of price. The average OTC discount in interdealer trades is 1.8 basis points of the mid-price, and again we observe that, on average, OTC discount is larger for bilateral OTC trades (2.1 basis points) than for trades via broker (1.6 basis points) in interdealer trades.

[Table A.5 about here.]

Table A.5 presents the results of regressing OTC discount as defined in Equation (9) on proxies of search-and-bargaining and information frictions as described in Section 4.4 and Table 4. The estimation results are in line with our previous findings, and since our definition of OTC discount has changed greatly, we abstain from comparing coefficient magnitudes. For information frictions we find that bilateral trades with a higher price impact feature lower discounts, and the presence of order splitting also relates to a significantly lower discount. With regard to search-and-bargaining frictions, we find that trades that take place on more volatile bond-days, and that are larger feature a lower discount.

[Table A.6 about here.]

Table A.6 presents the results of regressing OTC discount measured as a share of price on the matched sample described in Section 4.5. We find that trades via brokers receive, on average, $0.47 - 0.57$ basis points (of mid-price) less discount than comparable bilateral OTC trades, in line with our previous findings.

D OTC Discount in the Dealer-to-Customer Segment

In this Appendix we extend our analysis for OTC discount to the dealer-to-customer (D2C) segment of the Bund market. The dealer-to-customer (D2C) segment of the

Bund market is dominated by bilateral OTC interactions between dealers and customers. Electronic platforms with a non-negligible market share are either mostly used as a pre-arranged trade facility or follow request-for-quote protocols. The Bund D2C segment is thus similar to the U.S. corporate bond market (O'Hara and Zhou, 2021) and other typical OTC markets. Panel A of Table A.7 provides summary statistics on trading activity in this segment. There are about 123,000 dealer-to-customer trades between MTS dealers and their clients (labeled "D2C"). The average trade size of D2C trades is 6.7 million EUR. For ease of comparison with the D2D trades, we also impose a minimum trade size of 2.5 million EUR. This results in about 48,500 trades worth 779 billion EUR. For our later analysis we consider only bilaterally negotiated D2C trades where the dealer is directly reporting in our transactions data (i.e. a German financial institution) and where the trade was initiated by the customer according to our trade sign identification, and we report the statistics for the respective subsample labeled as "customer-initiated" in Table A.7. Comparing the cross-sectional distributions of the latter two subsamples suggests that there are only minor differences in terms of trade size. The D2C segment of the Bund market is dominated by bilateral OTC interactions between dealers and customers, which account for more than 90% of D2C volume throughout our sample period. Electronic platforms with non-negligible market shares are either mostly used as pre-arranged trade facilities or follow request-for-quote protocols.

[Table A.7 about here.]

We also compute the OTC discount for our sample of D2C trades. While the bid and ask prices on MTS are not actually attainable by customers, they serve as reference prices that are easily observable by traders. OTC discount thus captures the transaction cost advantage relative to trading conditions on the interdealer exchange. The average OTC discount across all D2C trades in our sample, reported in Panel B of Table A.7, is 49.8%, only slightly less than for bilateral D2D transactions. When we restrict the D2C sample to trades below 2.5 million EUR, this number is 43.0%. In the subsample of customer-initiated D2C trades with a trade size of at least 2.5 million EUR the average OTC discount is 44.0%. Only 12.1% of these trades incur an OTC premium.

These summary statistics suggest that dealers pass on a substantial share of their trading advantage to their clients. Note that the observation that client trades receive a similar OTC discount as interdealer trades does not imply that dealers are losing money. Dealers likely earn a profit from market making by matching a large fraction of trades internally. Our results differ from those of similar studies of dealer-to-customer markets with hybrid settings that involve OTC segments and electronic request-for-quote (RFQ) platforms. There, trading costs are typically lower for D2C trades via RFQ, as documented by Hendershott and Madhavan (2015) and O'Hara and Zhou (2021) for U.S. corporate bonds and Hau, Hoffmann, Langfield and Timmer (2021) for foreign exchange derivatives. These results are consistent with Vogel (2019) who develops a theory for such a setup and studies under which conditions the introduction of RFQ platforms can improve welfare over pure OTC markets. Dealers in RFQ markets are typically able to identify (and often pre-select) the traders requesting quotes via the electronic RFQ platform. Our empirical setting is different as we compare the pricing of OTC trades with a limit order book. In related work, Dunne, Hau and Moore (2015) find that prices of client-to-dealer trades in European sovereign bonds on 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.

To gauge whether the preferential pricing in the OTC segment has broader implications for the Bund market, we now analyze whether dealers pass on some of the discount to their clients, and under what conditions. Specifically, we seek to relate OTC discount of D2C trades to variables representing the dealer bargaining power, while controlling for search-and-bargaining and information frictions. We measure the dealer bargaining power with two variables. First, we use the dealer fixed effects (FE) obtained from estimating Equation (4) for bilateral interdealer trades (specification (1) of Table 4). Larger FE imply that a dealer achieves a higher OTC discount in the interdealer segment, controlling for other trade characteristics. We thus refer to these dealer FE as *excess bargaining power*.

Our second proxy for dealer bargaining power is the dealer's *overall trade volume*. This measure rests on the presumption that dealers with a higher total trading volume should generally be in a better bargaining position. For both proxies a positive coefficient implies that the dealer is passing on some of the OTC discount in the interdealer segment to her customers, while a negative coefficient implies that dealers exploit their bargaining power in trading with their clients. For the dealer FE the size of the coefficient can be interpreted as the rate of "pass-through" of the excess bargaining power of dealers in the D2D segment to their customers.

Formally we estimate

$$OTC\ discount_n = \beta' v_n + \varepsilon_n \tag{10}$$

at the level of individual trades (indexed by n), where v is a vector containing trade characteristics and controls as follows:

$$\begin{aligned}\beta' v_n = \beta_0 &+ \beta_1 \text{Price Impact}_n + \beta_2 \text{Order Splitting}_n \\ &+ \beta_3 \text{Aggregate Order Flow}_n + \beta_4 \text{Order Book Imbalance}_n \\ &+ \beta_5 \text{Volatility}_n + \beta_6 \text{Trade Size (log)}_n \\ &+ \beta_D \text{Dealer bargaining power}_n + \beta_b \Delta_b + \beta_j \Delta_j + \beta_C \text{Controls}_n.\end{aligned} \tag{11}$$

Δ_b and Δ_j are fixed effects for the bond traded and the involved client, respectively. Measures of intermediation frictions and controls are as before. *Dealer bargaining power* are the proxies outlined above, i.e. the *Dealer FE (D2D)* and *overall trade volume (dealer)*.

[Table A.8 about here.]

Table A.8 shows the results of this regression. We focus on bilaterally negotiated D2C trades that are initiated by the customer and where the dealer is reporting to our transactions data. For comparability with our previous results we also consider only trades with a size of at least 2.5 million EUR.

In specification (1) of Table A.8 we regress the D2C OTC discount on trade characteristics without considering the role of dealers. Interestingly, the results are similar to those in the D2D segment, even in magnitude. Specifically, D2C OTC discount is smaller for trades with a larger price impact, in the presence of order splitting and for trades against the aggregate order flow of the market. Similarly, OTC discount is lower when volatility is high and for larger trades. Hence, liquidity conditions on the exchange are not fully passed on to the D2C segment. These findings are consistent with dealers offering trading conditions in the D2C segment in accordance with the corresponding trading conditions in the interdealer segment.

Specifications (2) and (3) additionally include dealer bargaining power. The estimation coefficients for these variables are positive and significant in the case of overall dealer volume, implying that customers benefit from trading with dealers with more bargaining power in the D2D segment. A one standard deviation higher dealer volume corresponds to a 3.4 percentage points higher OTC discount for the client. We leave for future research the question whether this result is driven by customer informedness as suggested by Pinter et al. (2020) and Kondor and Pinter (2021).

Our results are robust with respect to several important dimensions. First, we lower the minimum trade size for the D2C segment to 100,000 EUR thereby substantially increasing the number of trades. The results are shown in specifications (4) - (6) and are quantitatively and qualitatively in line with our previous results. Most notably, the coefficient for Dealer fixed-effects is now significant in specification (5).

In summary, we observe that larger dealers, or dealers with more bargaining power in the interdealer segment, offer lower transaction costs to their clients. We conjecture that this might be due to a network feedback effect: more D2C interactions give dealers a better grasp of market conditions, thereby supporting their performance in the D2D segment and enabling them to offer better quotes in D2C segment, which again leads to more D2C trades.

Consistent with our findings, Hollifield, Neklyudov and Spatt (2017) find that spreads are lower for customers trading with core instead of peripheral dealers in the securitization market. They explain this with differentially sophisticated clienteles of each group of dealers. Note that since we include client-fixed effects in the regressions, our findings capture effects beyond those explained by differences in client sophistication. Li and Schürhoff (2019) document that in the U.S. municipal bond market more central dealers charge investors higher transaction costs, but also provide more immediacy. Our contrasting result might reflect the different architecture of these markets. In the municipal bond OTC market centrality plays a key role for the provision of immediacy, implying that only the most central dealers can provide a high degree of immediacy. Instead, the hybrid D2D Bund market structure gives all dealers virtually the same access to immediacy through the exchange, and might thus mute the effects of speed differentials on D2C liquidity provision and transaction costs.

E Multinomial Protocol Choice Model

In Section 4.1 we describe how we model dealers' protocol choice as a sequential decision, involving two probit stages. Here we provide an alternative specification using a multinomial logit model. The results, shown in Table A.9, are in line with those in the main text of the paper.

[Table A.9 about here.]

F Descriptive Statistics of Explanatory Variables

In Table A.10 we provide definitions of all variables used in our analysis. The variables' definition generally take the point of view from the trader initiating the transaction, i.e. requesting liquidity from other dealers.

Table A.11 presents descriptive statistics of the explanatory variables. We distinguish for the samples defined in Table 1 and Section 2. Panels A, B, and C refer to interdealer trades with a minimum size of 2.5 million EUR, where Panel A refers to interdealer trade on the exchange MTS, Panel B to bilaterally negotiated interdealer trades, and Panel C to interdealer trades via a broker. Panel D refers to the set of customer-initiated dealer-to-customer (D2C) trades with a minimum size of 2.5 million EUR.

[Tables A.10 and A.11 about here.]

Table A.1. Descriptive Statistics of OTC Discount: with walking up the book. *OTC discount*, as defined in Appendix C, 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 (including the effects of consuming liquidity from deeper levels of the limit order book, i.e. "walking up the book"), measured as a share of the effective MTS half-spread. It is given in percentage 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 1, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. For the calculation of mean and standard deviation we winsorize OTC discount for each subsample at the 0.5th and 99.5th percentile. The column *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent and p-value refers to a t-test of the mean being different from zero. Based on regulatory data of all transactions in Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,024	40.23	100.28	-96.25	36.00	67.14	85.71	96.67	12.3	0.0000
init. & counterp. ID known	209,427	50.22	66.81	-60.00	40.00	70.00	86.03	96.67	10.1	0.0000
D2D	45,032	47.59	71.37	-76.35	40.00	68.57	85.71	97.00	10.8	0.0000
trade size $\geq$ 2.5 million EUR	20,073	51.65	64.27	-66.67	43.16	71.56	87.50	97.37	10.6	0.0000
D2D via bilateral OTC	6,708	61.64	48.47	-6.37	53.31	74.64	88.00	96.91	5.4	0.0000
D2D via broker (D2B)	13,226	46.59	70.63	-91.42	36.15	69.59	87.18	97.67	13.2	0.0000

Table A.2. Intermediation Frictions and OTC Discount: with walking up the book. OLS estimation of $OTC\ discount_n = \gamma' v_n + \gamma_{\text{OTC}} \lambda_n^{\text{OTC}} + \gamma_s \lambda_n^s + \varepsilon_n$ (cf. Equation (4) and Section 4.4). The dependent variable, *OTC discount* 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, including the effects of consuming liquidity from deeper levels of the limit order book, i.e. "walking up the book", and measured as a share of the effective MTS half-spread (cf. Appendix C). v_n, as detailed in Equation (6), is a vector of variables representing search-and-bargaining and information frictions, and containing control variables, including fixed effects for bond and initiating dealer respectively. λ^{OTC} and λ^{s}, s $\in \{bilateral, broker\}$, are the Inverse Mills ratios controlling for protocol choice. The controls account for MTS half-spread, depth at the MTS best, issuance days, cheapest-to-deliver and on-the-run status, bond age, and end-of-quarter and end-of-year effects. The sample consists of bilaterally negotiated OTC trades between dealers in specifications (1) and (2) (row *D2D via bilateral OTC* in Table 1) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker (D2B)* in Table 1). The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data including all transactions in Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are obtained through sampling. t-values are given in parentheses and *, **, and *** denote significance at the 10%, 5%, and 1% level respectively.

Interdealer trading protocol:	bilateral OTC		via broker
	(1)	(2)	(3)
Price impact (15min)	-1.5631***	-1.5320**	-0.8951*
	(-2.6074)	(-2.5510)	(-1.8165)
Order splitting (dummy)	-4.7473***	-4.8781***	-2.8340***
	(-3.6591)	(-3.8667)	(-2.9783)
Aggregate order flow	-0.9562**	-0.9078*	-2.1207***
	(-2.0039)	(-1.9109)	(-5.3836)
Order book imbalance	-0.3033	-0.2225	0.5278
	(-0.6381)	(-0.4677)	(1.2273)
Inventory	-1.0569**	-0.8985*	0.0331
	(-2.0921)	(-1.9274)	(0.0738)
Volatility	-9.3207***	-9.4847***	-13.7131***
	(-8.9818)	(-9.1875)	(-13.8709)
Trade size (log)	1.2836	0.8066	11.7235***
	(1.1544)	(1.2081)	(12.8092)
Top 5 dealer (dummy)		7.6475***	
		(6.3178)	
Bottom 5 dealer (dummy)		-33.7433***	
		(-3.6470)	
Inv. Mills OTC	-1.2585**	-1.1462**	0.6071
	(-2.4112)	(-2.2115)	(1.2857)
Inv. Mills bilateral	-0.8208	-1.1181	
	(-0.5981)	(-1.4530)	
Inv. Mills broker			-2.1122*
			(-1.7060)
Intercept	65.1958***	64.2510***	51.7526***
	(108.2267)	(102.2554)	(75.7577)
R^2	0.1169	0.1066	0.2499
R^2_{adjusted}	0.0946	0.0883	0.2416
R^2_{within}	0.0586	0.0674	0.1116
N	6,578	6,578	12,947
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Table A.3. Differences in OTC Discount across Interdealer Protocols: with walking up the book. OLS estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ (cf. Equation (7) and Section 4.5). The dependent variable, *OTC discount* 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, including the effects of consuming liquidity from deeper levels of the limit order book, i.e. "walking up the book", and measured as a share of the effective MTS half-spread (cf. Appendix C). v_n is a vector of trade and bond characteristics. It contains a dummy variable indicating whether an interdealer trade was via a broker, and variables representing search-and-bargaining and information frictions, as well as control variables, including fixed effects for bond and initiating dealer respectively. The controls account for MTS half-spread, depth at the MTS best, issuance days, cheapest-to-deliver and on-the-run status, bond age, and end-of-quarter and end-of-year effects. The sample consists of bilateral and broker OTC interdealer trades that are matched along the dimensions of trade size, MTS (half-)spread, date, bond and initiating dealer, among others. Further details of the matching process are described in Section 4.5. The minimum trade size is 2.5 million EUR in all specifications.

	(1)	(2)
Trade via broker (dummy)	-11.1037***	-12.7740***
	(-6.0450)	(-6.4211)
Price impact (15min)		0.1379
		(0.2097)
Order splitting (dummy)		-1.9023
		(-1.6818)
Aggregate order flow		-1.2988
		(-1.8777)
Order book imbalance		-0.6744
		(-1.7843)
Inventory		-0.2108
		(-0.2882)
Volatility		-4.9522***
		(-6.8565)
Trade size (log)		9.4158***
		(8.0130)
R^2	0.0872	0.1687
R^2_{adjusted}	0.0619	0.1425
R^2_{within}	0.0257	0.1127
N	4,194	4,194
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table A.4. Descriptive Statistics of OTC Discount: normalized by price. *OTC discount*, defined in Equation (9), 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, measured as a share of the quoted mid-price on MTS. It is given in 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 1, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. For the calculation of mean and standard deviation we winsorize OTC discount for each subsample at the 0.5th and 99.5th percentile. The column *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent and p-value refers to a t-test of the mean being different from zero. Based on regulatory data of all transactions in Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount (bp)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,033	2.92	6.82	-3.09	0.78	1.88	3.36	15.55	13.5	0.0000
init. & counterp. ID known	209,427	2.94	5.15	-2.00	0.90	1.95	3.36	14.55	11.3	0.0000
D2D	45,032	2.16	4.49	-2.83	0.71	1.71	2.82	11.49	13.2	0.0000
trade size $\geq$ 2.5 million EUR	20,073	1.77	4.29	-3.35	0.50	1.45	2.61	9.48	15.8	0.0000
D2D via bilateral OTC	6,708	2.10	3.26	-0.58	0.98	1.80	2.82	5.84	6.9	0.0000
D2D via broker (D2B)	13,226	1.59	4.70	-4.39	0.17	1.20	2.42	11.02	20.4	0.0000

Table A.5. Intermediation Frictions and OTC Discount: normalized by price. OLS estimation of $OTC\ discount_n = \gamma' v_n + \gamma_{\text{OTC}} \lambda_n^{\text{OTC}} + \gamma_s \lambda_n^s + \varepsilon_n$ (cf. Equation (4) and Section 4.4). The dependent variable, *OTC discount*, defined in Equation (9) in Section C, 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, measured as a share of the quoted mid-price on MTS. v_n, as detailed in Equation (6), is a vector of variables representing search-and-bargaining and information frictions, and containing control variables, including fixed effects for bond and initiating dealer respectively. λ^{OTC} and λ^{s}, s $\in \{$*bilateral*, *broker*$\}$, are the Inverse Mills ratios controlling for protocol choice. The controls account for MTS half-spread, depth at the MTS best, issuance days, cheapest-to-deliver and on-the-run status, bond age, and end-of-quarter and end-of-year effects. The sample consists of bilaterally negotiated OTC trades between dealers in specifications (1) and (2) (row *D2D via bilateral OTC* in Table 1) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker (D2B)* in Table 1). The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data including all transactions in Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are obtained through sampling. t-values are given in parentheses and *, **, and *** denote significance at the 10%, 5%, and 1% level respectively.

Interdealer trading protocol:	bilateral OTC		via broker
	(1)	(2)	(3)
Price impact (15min)	-0.1661**	-0.1716**	-0.1002
	(-2.1628)	(-2.2329)	(-1.3788)
Order splitting (dummy)	-0.2412***	-0.2233**	-0.1503*
	(-2.6012)	(-2.3866)	(-1.7499)
Aggregate order flow	0.0197	0.0232	-0.0932***
	(0.5602)	(0.6357)	(-2.6684)
Order book imbalance	0.0183	0.0135	0.0023
	(0.5325)	(0.3984)	(0.0848)
Inventory	-0.0687	-0.0440	-0.0947**
	(-1.6185)	(-1.2792)	(-2.4557)
Volatility	-0.8377***	-0.8468***	-1.5643***
	(-5.1791)	(-5.2523)	(-11.1716)
Trade size (log)	-0.4466***	-0.3565***	-0.2014**
	(-3.6855)	(-5.1360)	(-2.5081)
Top 5 dealer (dummy)		0.3291***	
		(4.1170)	
Bottom 5 dealer (dummy)		-1.2948***	
		(-4.0038)	
Inv. Mills OTC	0.0559	0.0542	0.0689*
	(1.5167)	(1.4732)	(1.7128)
Inv. Mills bilateral	-0.0427	0.0400	
	(-0.3273)	(0.6044)	
Inv. Mills broker			-0.3842***
			(-3.6454)
Intercept	2.0705***	2.0688***	1.6080***
	(32.4452)	(30.7627)	(26.7585)
R^2	0.4769	0.4723	0.4414
R^2_{adjusted}	0.4636	0.4615	0.4352
R^2_{within}	0.2603	0.2651	0.2159
N	6,578	6,578	12,947
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Table A.6. Differences in OTC Discount across Interdealer Protocols: normalized by price. OLS estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ (cf. Equation (7) and Section 4.5). The dependent variable, *OTC discount*, defined in Equation (9) in Section C, 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, measured as a share of the quoted mid-price on MTS. v_n is a vector of trade and bond characteristics. It contains a dummy variable indicating whether an interdealer trade was via a broker, and variables representing search-and-bargaining and information frictions, as well as control variables, including fixed effects for bond and initiating dealer respectively. The controls account for MTS half-spread, depth at the MTS best, issuance days, cheapest-to-deliver and on-the-run status, bond age, and end-of-quarter and end-of-year effects. The sample consists of bilateral and broker OTC interdealer trades that are matched along the dimensions of trade size, MTS (half-)spread, date, bond and initiating dealer, among others. Further details of the matching process are described in Section 4.5. The minimum trade size is 2.5 million EUR in all specifications.

	(1)	(2)
Trade via broker (dummy)	-0.5698***	-0.4747***
	(-7.5583)	(-4.9304)
Price impact (15min)		0.0765
		(1.5551)
Order splitting (dummy)		-0.1079*
		(-2.2144)
Aggregate order flow		-0.0543
		(-1.5543)
Order book imbalance		-0.0488**
		(-2.6531)
Inventory		0.0098
		(0.4189)
Volatility		-0.2393***
		(-4.0568)
Trade size (log)		-0.0141
		(-0.1931)
R^2	0.4223	0.6698
R^2_{adjusted}	0.4063	0.6594
R^2_{within}	0.0160	0.4376
N	4,194	4,194
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table A.7. Trading Activity and OTC Discount by D2C Subsamples: This table provides summary statistics of trading activity (Panel A) and OTC Discount (Panel B) for subsamples of dealer-to-customer (D2C) trades used in the analysis of Appendix D. Panel A extends Table 1 and reports the number of trades for each subsample, the aggregated trade volume over our full sample period, and summary statistics of trade size (in terms of notional amount). Panel B extends Table 2. *OTC discount*, defined in Equation (1) in Section 3, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, measured as a share of the MTS half-spread. It is given in percentage points. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the interdealer exchange. For the calculation of mean and standard deviation we winsorize OTC discount for each subsample at the 0.5th and 99.5th percentile. The column *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent and p-value refers to a t-test of the mean being different from zero. In the dealer-to-customer segment (labeled *D2C*) we consider the subsample of trades with a minimum trade size of 2.5 million EUR. The row labeled *customer-initiated* refers to such trades initiated by the customer and where the dealer is a reporting entity to our transactions data (cf. also section 2.2). Based on regulatory data of all transactions in Bunds involving German financial institutions from June 2011 through December 2017.

Panel A: Trading Activity

	# trades	trade volume	trade size (million EUR)						
		(billion EUR)	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl
D2C	123,003	818.62	6.66	17.94	0.01	0.15	1.00	5.00	30.00
trade size $\geq$ 2.5 million EUR	48,543	779.07	16.05	25.87	3.00	5.00	6.60	15.05	50.00
customer-initiated	13,125	257.19	19.60	31.58	3.00	5.00	7.30	22.30	76.32

Panel B: OTC Discount

		OTC discount (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share <0 (%)	p-value (%)
D2C	122,963	49.78	67.15	-60.00	40.00	69.39	85.71	96.67	10.1	0.0000
trade size $\geq$ 2.5 million EUR	48,506	43.01	73.46	-80.00	33.33	65.00	83.33	96.00	12.4	0.0000
customer-initiated	13,125	43.95	74.96	-80.00	33.33	66.67	85.00	96.36	12.1	0.0000

Table A.8. OTC Discount in the D2C segment. OLS estimation of $\mathit{OTC\ discount}_n = \gamma' v_n + \varepsilon_n$ on dealer-to-customer trades (cf. Equation (10) and Appendix D). The dependent variable, *OTC discount*, defined in Equation (1) in Section 3, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, measured as a share of the MTS half-spread. v_n, as detailed in Equation (11), is a vector of trade and bond characteristics proxying for search-and-bargaining and information frictions, dealer-client characteristics, and containing control variables, including fixed effects for bond and initiating customer respectively. The controls account for MTS half-spread, depth at the MTS best, issuance days, cheapest-to-deliver and on-the-run status, bond age, and end-of-quarter and end-of-year effects. The sample consists of bilateral OTC trades between dealers and customers, where the dealer is a reporting entity to our transactions data and the trade was initiated by the customer (row *D2C – customer-initiated* in Table 1). The minimum trade size is 2.5 million EUR in specifications (1) - (3) and 100,000 EUR in specifications (4) - (6). Based on regulatory data of all transactions in Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, customer, and daily time level. t-values are given in parentheses and *, **, and *** denote significance at the 10%, 5%, and 1% level respectively.

Trade size:	$\geq$ 2.5 million EUR			$\geq$ 100,000 EUR		
	(1)	(2)	(3)	(4)	(5)	(6)
Price impact (15min)	-1.8080**	-1.7914**	-1.7717**	-1.3967***	-1.3893***	-1.3920***
	(-2.2513)	(-2.2333)	(-2.2179)	(-2.7935)	(-2.7793)	(-2.7733)
Order splitting (dummy)	-3.1906	-3.1959	-3.2461	-1.7768	-1.7249	-1.7580
	(-1.4085)	(-1.4104)	(-1.4429)	(-0.8476)	(-0.8230)	(-0.8406)
Aggregate order flow	-1.6009***	-1.5938***	-1.6358***	-1.0044***	-0.9919***	-1.0072***
	(-2.6274)	(-2.6208)	(-2.6948)	(-2.7324)	(-2.6999)	(-2.7519)
Order book imbalance	-1.1233*	-1.1191*	-1.1308*	-0.9244**	-0.9289**	-0.9411**
	(-1.7976)	(-1.7865)	(-1.8124)	(-2.1139)	(-2.1083)	(-2.1450)
Volatility	-7.2494***	-7.1906***	-7.0843***	-7.1054***	-7.0995***	-7.0662***
	(-4.6816)	(-4.6324)	(-4.6101)	(-7.3366)	(-7.4408)	(-7.4368)
Trade size (log)	-3.5831***	-3.5855***	-3.6226***	-1.3296*	-1.3446*	-1.2371*
	(-3.4283)	(-3.4284)	(-3.4585)	(-1.8862)	(-1.9230)	(-1.7611)
Dealer FE (D2D)		0.9825			2.2246***	
		(0.8436)			(2.6912)	
Overall trade volume (dealer)			3.3809***			3.0341***
			(2.9897)			(3.5325)
R^2	0.3171	0.3172	0.3184	0.3001	0.3009	0.3017
R^2_{adjusted}	0.2524	0.2524	0.2537	0.2588	0.2596	0.2604
R^2_{within}	0.0377	0.0378	0.0396	0.0327	0.0339	0.0349
N	5,664	5,664	5,664	12,383	12,383	12,383
Bond FE	yes	yes	yes	yes	yes	yes
Customer FE	yes	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes	yes

Table A.9. Probability Model for Protocol Choice: multinomial logit specification. This table reports the marginal effects of a multinomial logit model for protocol choice, as described in Appendix E. The sample consists of interdealer trades for a minimum trade size of 2.5 million EUR (rows *D2D via MTS*, *D2D via bilateral OTC*, and *D2D via broker (D2B)* in Table 1. Controls account for MTS half-spread, depth at the MTS best, cheapest-to-deliver and on-the-run status, bond age, coupon rate, maturity at issuance, and amount outstanding, issuance days, and end-of-quarter effects and end-of-year effects. Based on regulatory data including all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Z-scores are given in parentheses where standard errors are clustered at the dealer level and *, **, and *** denote significance at the 10%, 5%, and 1% level respectively.

Interdealer trades:	MTS	bilateral	via broker
	(1)	(2)	(3)
Order splitting (dummy)	0.0217***	-0.0424***	0.0207
	(3.4835)	(-2.9460)	(1.5503)
Aggregate order flow	-0.0033	-0.0065	0.0098***
	(-1.2468)	(-1.2537)	(2.7177)
Order book imbalance	-0.0027	0.0042	-0.0014
	(-1.5714)	(1.3353)	(-0.4564)
Inventory	-0.0083***	-0.0164**	0.0247***
	(-2.9910)	(-2.4993)	(3.7906)
Volatility	0.0340***	-0.0172*	-0.0168*
	(7.9555)	(-1.6787)	(-1.6559)
Dealer Volume	0.0176	-0.1392***	0.1216**
	(0.8792)	(-2.8449)	(2.3858)
Trade size 10-30 million EUR (dummy)	-0.0215**	-0.1770***	0.1985***
	(-1.9981)	(-3.8535)	(4.6176)
Trade size > 30 million EUR (dummy)	-0.1017***	-0.2737***	0.3754***
	(-3.1112)	(-5.3931)	(9.1746)
Round trade size (2.5/5/10 mn EUR, dummy)	0.1705***	0.0064	-0.1769***
	(10.7308)	(0.2434)	(-7.1370)
R^2_{pseudo}		0.2711	
N		22,234	
Controls		yes	

Table A.10. 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 3 and Equation (1).	transactions, MTS & 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
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. For example, 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 than on the bid side has positive sign.	transactions, MTS & own calculations	n
Inventory	Dealer's net imbalance over all Bunds on the same day prior to the trade, measured as a share of her average daily trading volume. The measure is signed so that it is positive for trades increasing a dealer's net inventory position in absolute value.	transactions & own calculations	n
Volatility	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
Dealer volume	Overall trade volume of the dealer. Nominal amount in trillion EUR.	transactions	i
Trade size (log)	Logarithm of market value of trade, where market value is in EUR.	transactions	n
Trade size $10 - 30$ million EUR (dummy)	Equals one if 10 million EUR $\leq$ nominal trade size $\leq$ 30 million EUR.	transactions	n
Trade size $>$ 30 million EUR (dummy)	Equals one if nominal trade size $>$ 30 million EUR.	transactions	n
Round trade size (dummy)	Equals one if the nominal value of the trade is 2.5, 5, or 10 million EUR, and zero otherwise.	transactions	n

Table A.10 continued on next page.

Table A.10 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
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
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
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
Inv. Mills OTC	Inverse Mills ratio for the choice of trading OTC instead of on exchange. Calculated as $\textit{Inv. Mills OTC}_n = \phi(\gamma'\omega_n)/\Phi(\gamma'\omega_n)$, where ϕ and Φ are the probability and cumulative density functions of the standard normal distribution, and γ is obtained from the estimation of Equation (2) in Table 3, specification (1), cf. section 4.3.	own calculations	n
Inv. Mills Bilateral	Inverse Mills ratio for the choice of trading bilaterally (instead of via broker) if a trade is taking place OTC. Calculated as $\textit{Inv. Mills Bilateral}_n = \phi(\gamma'\omega_n)/\Phi(\gamma'\omega_n)$, where γ is obtained from the estimation of Equation (3) in Table 3, specification (2), cf. section 4.3.	own calculations	n
Inv. Mills Broker	Inverse Mills ratio for the choice of trading via broker (instead of bilaterally) if a trade is taking place OTC. Calculated as $\textit{Inv. Mills Broker}_n = -\phi(\gamma'\omega_n)/(1-\Phi(\gamma'\omega_n))$, where γ is obtained from the estimation of Equation (3) in Table 3, specification (2), cf. section 4.3.	own calculations	n

Table A.11. Statistics of Explanatory Variables: Descriptive statistics of explanatory and control variables as defined in Table A.10. The sample consists of interdealer trades for a minimum trade size of 2.5 million EUR for the following samples (as defined in Table 1): Panel A refers to all trades on the interdealer exchange MTS in our transactions data, Panel B to bilaterally negotiated interdealer trades and Panel C to interdealer trades via a broker. Based on regulatory data of all transactions in 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)	15.78	0.53	14.80	15.45	15.79	16.14	16.46	2,179
Round trade size (dummy)	0.83							2,179
Inventory (%)	0.19	0.22	0.00	0.00	0.10	0.31	0.66	2,179
Volatility (bp)	1.73	2.51	0.10	0.28	0.74	2.12	7.13	2,176
Price impact (15min, in bp)	1.53	6.28	-3.46	0.00	0.49	1.88	10.91	2,138
Order splitting (dummy)	0.38							2,179
Aggregate order flow (bn EUR)	-0.01	0.48	-0.75	-0.20	-0.00	0.19	0.69	2,179
Order book imbalance (mn EUR)	-1.30	28.66	-32.75	-7.25	-0.00	10.00	25.55	2,179
MTS half-spread (bp)	3.31	5.40	0.25	0.80	1.50	3.00	15.00	2,179
Depth at MTS best (log)	15.96	0.76	14.73	15.42	16.12	16.12	17.50	2,179
Dealer Volume (tn EUR)	0.30	0.30	0.00	0.01	0.11	0.65	0.67	2,179
Issuance day (dummy)	0.05							2,179
Cheapest-to-deliver (dummy)	0.04							2,179
Amount outstanding (log)	23.51	0.37	22.52	23.43	23.56	23.72	23.90	2,179
Bond age (%)	47.82	32.06	1.19	17.47	47.31	79.18	94.18	2,179
Coupon rate (%)	2.24	1.77	0.00	0.50	2.00	3.75	5.00	2,179
End-of-quarter (dummy)	0.05							2,179
End-of-year (dummy)	0.01							2,179
Recent on-the-run (dummy)	0.10							2,179
2-year Schaetze (dummy)	0.21							2,179
5-year Bobl (dummy)	0.22							2,179
30-year Bund (dummy)	0.12							2,179

Table A.11 continued on next page.

Table A.11 continued from previous page.
Panel B: D2D via bilateral OTC

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Trade size (log)	15.90	0.89	14.85	15.22	15.60	16.37	17.74	6,791
Round trade size (dummy)	0.26							6,791
Inventory (%)	0.21	0.23	0.00	0.01	0.13	0.34	0.69	6,791
Volatility (bp)	1.69	2.58	0.11	0.51	1.25	2.28	4.59	6,789
Price impact (15min, in bp)	0.27	3.86	-4.89	-0.87	0.00	1.24	5.91	6,582
Order splitting (dummy)	0.22							6,791
Aggregate order flow (bn EUR)	0.02	0.52	-0.79	-0.18	0.01	0.21	0.83	6,791
Order book imbalance (mn EUR)	1.53	15.14	-20.00	-5.00	0.00	10.00	20.00	6,791
MTS half-spread (bp)	4.12	4.80	1.20	2.10	3.00	4.00	9.50	6,791
Depth at MTS best (log)	15.87	0.64	14.51	15.42	16.12	16.12	16.81	6,791
Dealer Volume (tn EUR)	0.26	0.27	0.00	0.02	0.11	0.42	0.67	6,791
Issuance day (dummy)	0.02							6,791
Cheapest-to-deliver (dummy)	0.07							6,791
Amount outstanding (log)	23.57	0.32	23.03	23.50	23.61	23.77	23.90	6,791
Bond age (%)	36.74	28.46	1.54	8.66	33.53	57.25	89.66	6,791
Coupon rate (%)	1.98	1.49	0.00	0.50	1.75	3.25	4.25	6,791
End-of-quarter (dummy)	0.05							6,791
End-of-year (dummy)	0.01							6,791
Recent on-the-run (dummy)	0.17							6,791
2-year Schaetze (dummy)	0.10							6,791
5-year Bobl (dummy)	0.24							6,791
30-year Bund (dummy)	0.05							6,791
Inv. Mills OTC	0.15	0.23	0.00	0.02	0.05	0.20	0.63	6,789
Inv. Mills bilateral	-0.87	0.35	-1.50	-1.09	-0.83	-0.61	-0.36	6,789

Table A.11 continued on next page.

Table A.11 continued from previous page.
Panel C: D2D via broker (D2B)

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Trade size (log)	16.73	1.02	14.96	15.91	16.95	17.57	18.35	13,282
Round trade size (dummy)	0.13							13,282
Inventory (%)	0.22	0.22	0.00	0.03	0.15	0.34	0.66	13,282
Volatility (bp)	2.09	8.04	0.13	0.53	1.41	2.54	6.35	13,269
Price impact (15min, in bp)	0.11	5.00	-6.34	-0.98	0.00	1.31	6.84	12,963
Order splitting (dummy)	0.32							13,282
Aggregate order flow (bn EUR)	0.04	0.51	-0.71	-0.16	0.02	0.24	0.88	13,282
Order book imbalance (mn EUR)	1.01	14.98	-20.00	-5.00	-0.00	10.00	20.00	13,282
MTS half-spread (bp)	5.11	7.05	1.00	2.00	3.00	4.00	23.00	13,282
Depth at MTS best (log)	15.89	0.65	14.51	15.42	16.12	16.12	16.81	13,282
Dealer Volume (tn EUR)	0.32	0.24	0.03	0.09	0.22	0.65	0.67	13,282
Issuance day (dummy)	0.07							13,282
Cheapest-to-deliver (dummy)	0.16							13,282
Amount outstanding (log)	23.49	0.39	22.33	23.36	23.61	23.72	23.90	13,282
Bond age (%)	29.71	27.74	0.94	5.60	20.05	50.19	85.53	13,282
Coupon rate (%)	1.85	1.56	0.00	0.50	1.50	3.25	4.25	13,282
End-of-quarter (dummy)	0.03							13,282
End-of-year (dummy)	0.00							13,282
Recent on-the-run (dummy)	0.21							13,282
2-year Schaetze (dummy)	0.13							13,282
5-year Bobl (dummy)	0.22							13,282
30-year Bund (dummy)	0.11							13,282
Inv. Mills OTC	0.10	0.20	0.00	0.01	0.02	0.07	0.52	13,269
Inv. Mills broker	0.45	0.33	0.09	0.20	0.34	0.62	1.09	13,269

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