Calebe de Roure | Emanuel Moench | Loriana Pelizzon | Michael Schneider

OTC Discount

SAFE Working Paper No. 298

Leibniz Institute for Financial Research SAFE
Sustainable Architecture for Finance in Europe
info@safe-frankfurt.de | www.safe-frankfurt.de

OTC Discount

Calebe de Roure[a], Emanuel Moench[b,c], Loriana Pelizzon[d,e], and Michael Schneider[d,f]

[a]Reserve Bank of Australia
[b]Frankfurt School of Finance and Management
[c]CEPR
[d]Leibniz Institute for Financial Research SAFE
[e]Ca' Foscari University of Venice
[f]Deutsche Bundesbank

January 19, 2024

Abstract

We document a pecking order of transaction costs in the interdealer market for German sovereign bonds, where three trading protocols coexist. Dealers can trade over-the-counter, either bilaterally or via brokers, as well as on an exchange. Trading on the exchange is more expensive than OTC, and broker-intermediated are more costly than bilateral OTC trades. The existence of an OTC discount is difficult to square with theories centred around search-and-bargaining frictions, but is in line with models of hybrid markets based on information frictions. Consistently, we show that dealers' information impacts their choice of trading protocol and that the pecking order of transaction costs is aligned with the informational content of order flows across protocols. Search-and-bargaining as well as information proxies explain differences in OTC discount within protocols. A realistic description of hybrid markets thus requires both types of 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

This paper represents the views of the authors and does not necessarily reflect the views of the Reserve Bank of Australia, the Deutsche Bundesbank, or the Eurosystem. Authors' email addresses: deRoureC@rba.gov.au, e.moench@fs.de, pelizzon@safe-frankfurt.de, and schneider.michael.t@gmail.com. We are thankful for the comments from participants at the 8th Bundesbank Term Structure Workshop, the 31st Australasian Finance and Banking Conference, the 16th Paris December Finance Meeting, the 6th International Conference on Sovereign Bond Markets, the 2019 Annual Meeting of the Swiss Society for Financial Market Research, the 2nd Workshop on OTC Markets, the 12th Annual Meeting of the Society for Financial Econometrics, the 27th Finance Forum, and the 26th Annual Meeting of the German Finance Association (DGF), as well as Mario Bellia, Pierre Collin-Dufresne, Marco Di Maggio, Darrell Duffie, Peter Egger, Michael Fleming, Yalin Gündüz, Terrence Hendershott, Edith Hotchkiss, Sven Klingler (discussant), Juliane Krug (discussant), Tomy Lee (discussant), Fabrizio Lillo, Albert Menkveld, Florian Nagler (discussant), Stanislava Nikolova, Christian Opp, Roberto Pascual (discussant), Paolo Pasquariello, Angelo Ranaldo, Torsten Rothe, Stephen Schaefer, Kathi Schlepper, Norman Schürhoff (discussant), Philipp Schuster (discussant), Duane Seppi, Marti G. Subrahmanyam, Sebastian Vogel (discussant), Thomas Weinberg, Haoxiang Zhu, and numerous market participants. All errors are our own. Pelizzon and Schneider acknowledge funding by the Deutsche Forschungsgemeinschaft (DFG) – 329107530. Pelizzon thanks the Leibniz Institute for Financial Research SAFE for financially sponsoring this research. Corresponding author: Loriana Pelizzon.

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. Instead, in some asset classes dealers trade with one another on electronic central limit order books provided by exchange platforms. In contrast to OTC markets, search-and-bargaining frictions are irrelevant on the exchange where all participants can immediately trade at the same prices. In practice, OTC and exchange platforms often co-exist as hybrid markets.

The dealer-to-dealer (D2D) segment of the market for German sovereign bonds (Bunds) is a case in point. We document that the vast majority of OTC Bund trades have lower transaction costs than those implied by exchange quotes, thus giving rise to a pervasive *OTC discount*. A substantial share of these OTC transactions is intermediated by inter-dealer brokers. Distinguishing between bilaterally negotiated and broker-intermediated OTC trades, we show that the latter feature a considerably lower OTC discount. We thus observe a pecking order of transaction costs: exchange trading is more expensive than via brokers, and broker-intermediated are more costly than bilateral OTC trades.

These findings are difficult to square with theories that exclusively focus on search-and-bargaining frictions. If search was the only friction, then traders with access to an exchange should not have a reason to trade bilaterally. That said, the existence of a hybrid market and our finding of an OTC discount are consistent with theories emphasizing the role of asymmetric information which gives rise to adverse selection. In line with this view, we document that dealers' choice of trading protocol is driven by variables measuring the private and market-wide information that they have access to. Moreover, we show that the pecking order of transaction costs is aligned with the informational content of order flows across protocols for Bund returns. Finally, our results imply that the observed variation of transaction costs *within* OTC protocols is driven by information as well as search-and-bargaining frictions. Combined, our analysis suggests that a realistic description of hybrid markets requires both types of frictions. This is relevant given recent efforts to regulate OTC markets more tightly and to foster exchange-based trading.

In the interdealer Bund market dealers trade with each other using three different protocols: via the interdealer exchange MTS, via interdealer brokers, and through bilateral negotiations. Trading on the exchange is immediate and post-trade transparent. As such it eliminates search-and-bargaining frictions but can also reveal private information since all market participants instantaneously observe the price and volume of each trade. In contrast, for bilateral and broker-intermediated OTC transactions only the involved counterparties observe a trade. In bilateral OTC transactions dealers search for counterparties and therefore know their identities. Instead, when they trade via a broker, this search effort is undertaken by the broker and counterparties remain anonymous to one another. For each trade, dealers can thus choose between three protocols which differ with respect to anonymity, transparency and immediacy. Hence, their trading decisions depend on the relative importance of search-and-bargaining as well as information frictions across protocols. What the presence of these frictions implies for the ranking of transaction costs is an empirical question.

The D2D Bund market represents an ideal laboratory to study this question. 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 transaction cost than the one attainable on MTS. Moreover, there is a sizable difference between the OTC discounts of bilateral and broker-intermediated OTC trades. While bilateral OTC trades on average feature 54.6% lower transaction costs relative to exchange quotes, broker trades are on average only 24.6% cheaper. This pecking order of transaction costs is highly economically significant in light of an annual trading volume of about 1.6 trillion EUR in the interdealer Bund market.

[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*.

More than three quarters of interdealer trading volume in the Bund market is intermediated by brokers. Why do dealers rely so heavily on brokers despite the higher transaction costs relative to bilateral OTC trades? Moreover, why do dealers trade on the exchange even though it is more costly than in the OTC protocols? We study both questions by modeling dealers' protocol choice at the level of individual trades and rely on several proxies of information and search-and-bargaining frictions as explanatory variables. We find that both types of frictions are relevant for dealers' protocol choice. More informed trades are more likely routed via the exchange. Similarly, more informed OTC transactions are often intermediated by a broker. Finally, we also show that proxies for search frictions influence dealers' protocol choice. Combined, these results highlight the complementary roles that the three protocols provide.

We document that dealers' individual trading decisions are also reflected in the informational content of aggregate order flows across protocols. Regressing bond returns on the lagged order flows from all three protocols, 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 more pronounced for the exchange. We find no predictability for the flow from bilateral interdealer trades. Crucially, this is consistent with the observed pecking order and our finding that more informed trades are more likely routed via the exchange or a broker.

To assess the relative importance of search-and-bargaining and information frictions in determining transaction costs *within* protocols, we estimate a transaction-level regression of OTC discount on proxies of both types of frictions. Importantly, our results account for the potential endogeneity arising from the joint determination of the choice of trading protocol and pricing decisions. We find that more informed OTC trades receive significantly lower discounts. Moreover, dealers with more bargaining power receive higher discounts, suggesting that both types of frictions are quantitatively important drivers of OTC discount. 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.

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, 2022). 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). Therefore, it is a widely held view that exchange markets feature lower transaction costs than OTC markets if considered separately (Edwards, Harris, and Piwowar, 2007; Bessembinder, Spatt, and Venkataraman, 2020).

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; Yoon, 2019; Glode and Opp, 2020; Lee and Wang, 2023).[2] In Lee and Wang (2023), dealers price discriminate between traders who are publicly labeled as being either likely informed or likely uninformed. Traders choose between trading on an exchange or over-the-counter. Their model predicts that "the exchange spread is strictly wider than the OTC spread". Consistent with their predictions we find that OTC transaction costs for Bunds are lower than on the exchange.

Some prior work relates information to order flows (Burdett and O'Hara, 1987; Grossman, 1992; Brancaccio, Li, and Schürhoff, 2020; Colliard and Demange, 2021; Czech, Huang, Lou, and Wang, 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. In the Gilt market, Czech et al. (2021) show that some customers' order flows carry information about 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 and highlighting the role of transparency.

[2]The previous literature has also associated heterogeneity in traders' asset valuations and other trading needs with differences in transaction costs and venue choices in hybrid markets (e.g. Pagano, 1989; Chowdhry and Nanda, 1991; Babus and Parlatore, 2022; Dugast, Üslü, and Weill, 2022).

Relevant information can also be about the identity of traders. Meling (2021) investigates the role of post-trade anonymity on market quality. He shows that the introduction of post-trade anonymity on the Oslo stock exchange increased trading volume and improved bid-ask spreads. This is in line with our results which also point to the relevance of anonymity for trading decisions. Specifically, we find that dealers frequently accept lower OTC discounts to trade via brokers who provide anonymity.

Several papers have empirically studied pricing and protocol choice in hybrid markets in different asset classes. 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. More recently, Allen and Wittwer (2023) study traders' venue choice in the Canadian sovereign bond market and analyse the welfare implications of modifications to the hybrid market setting. Investigating 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 on a limit order book. Studying the introduction of OTC trading to the Chinese interbank FX market Holden, Lu, Lugovskyy, and Puzzello (2021) provide evidence for the role of bargaining power by comparing the aggregate price functions of small and large banks.

A key advantage of our analysis is that we can directly compare the transaction costs for exchange and OTC trading as well as measure the relevant frictions at the transaction level. Relatedly, a number of papers have analyzed alternative protocols for equities, such as upstairs markets (e.g., Bessembinder and Venkataraman, 2004). Moreover, Menkveld, Yueshen, and Zhu (2017) observe that volatility shocks shift market shares between dark and lit venues along a pecking order reflecting different degrees of immediacy. We complement their analysis by showing that the three trading protocols for which we document a pecking order of transaction cost differ not only in terms of immediacy but also along the additional dimensions of transparency and anonymity.

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 (2023) argue that brokers help facilitate liquidity provision. In the U.S. Treasury market, Anderson and Liu (2023) 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.S. Treasuries (Copeland, Fleming, Keane, and Mithal, 2018), 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.

In sum, our findings point to a gap in the theoretical literature on OTC and exchange markets. A realistic description of the prevalent market structure should consider the coexistence of more than two different trading protocols, and especially the important role of interdealer brokers. Moreover, it should account for both information and search-and-bargaining frictions in a unified framework.

The remainder of this paper proceeds as follows. Section 2 describes the Bund market and the features of the three trading protocols, as well as our dataset. Section 3 introduces our main quantity of interest, OTC discount, and establishes a pecking order of transaction costs across protocols. In Section 4 we relate dealers' protocol choice to proxies of information and search-and-bargaining frictions. We also show that the pecking order is consistent with the informational content of order flows across protocols. In Section 5 we study the role of both types of frictions in driving differences of OTC discount within trading protocols. Section 6 concludes.

2 The Bund Market

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: the interdealer exchange MTS, over-the-counter transactions intermediated by interdealer brokers, or bilateral OTC transactions. In this section, we describe the market structure of the three protocols and highlight their properties in terms of transparency and anonymity.[3]

2.1 Trading Protocols and Market Structure

Exchange. The first option for Bund dealers to trade is via an exchange. The main exchange 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 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. Subscription services such as Bloomberg disseminate MTS prices and volumes at the best bid and ask levels in real time. Hence, this information is available also to non-MTS dealers. Similarly, all trading activity on the exchange is observed by all market participants in an anonymized way. Hence, MTS provides both pre-trade transparency (about trading conditions) and post-trade transparency (about executed trades). After a trade occurs, the identity of the counterparties is revealed only to the two involved dealers for the purpose of settlement. This protocol therefore provides anonymity pre-trade and post-trade from non-involved parties.

Bilateral. Dealers trade directly with one another in bilateral over-the-counter negotiations. This protocol represents the classical OTC trading protocol studied in most of the literature on OTC bond markets. Bilateral OTC trading is neither pre-trade nor

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

post-trade transparent (trades are observed by the counterparties but not by other market participants). In these bilateral trades both involved dealers are aware of the identity of their counterparty, i.e. bilateral trades are not anonymous for the counterparties involved. Other market participants do not observe any information about the trade.

Interdealer brokers. 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. According to conversations with market participants, broker trades in the Bund market are still commonly done by voice. Just as bilateral OTC trades, broker trades are not transparent and unobserved by other market participants.[4] Crucially, brokers 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.[5] This protocol, therefore, also provides anonymity both pre- and post-trade, since the broker masks the identity of the other counterparty.

In what follows, we refer to bilateral and broker trades jointly as *OTC trades*, in contrast to exchange trades on MTS.

[Table 1 about here.]

Table 1 summarizes the transparency and anonymity features of the three protocols. The main differences between the three protocols are as follows. First, exchange trading is pre- and post-trade transparent, while OTC trades are not and thus unobserved by other market participants. Second, in bilateral trades dealers are aware of each others' identity while the involved counterparties are anonymous in broker-intermediated trades. On the exchange, the identities of the counterparties are only revealed post-trade to the involved dealers for settlement purposes. Third, trading on the exchange is immediate whereas both OTC protocols include search-and-bargaining processes.

[4]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.

[5]See the AFME European Primary Dealers Handbook available at `https://www.afme.eu/portals/0/globalassets/downloads/publications/afme-primary-dealers-handbook-q3-2017.pdf`, and Appendix A for institutional background on interdealer brokers.

Importantly, all three trading protocols are simultaneously available to dealers, and in our sample dealers rely on all of them. The fact that all three protocols are regularly used suggests that they offer complementary features to dealers for different trades. Of note, 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. Interestingly, this market structure differs from that studied in most theoretical models which, to the best of our knowledge, do not consider all three protocols jointly.

2.2 Data

We focus on German sovereign bonds with maturities of 2, 5, 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 interdealer trades from all three market segments, in addition to bilateral D2C trades. 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 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 2 about here.]

Table 2 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 protocol. 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 2).[6] 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"), both in terms of number of trades (about 13,300) and overall volume (77.9%).[7] The average nominal trade size in the interdealer segment is 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.

[6]For a detailed description of the dataset and our matching approach please refer to Appendix B.

[7]This figure is in line with evidence provided by Pinter, Wang, and Zou (2022) for the UK Gilt interdealer market.

3 OTC Discount in the Bund Interdealer Market

In this section, we document that transaction costs in the interdealer Bund market are on average lower for OTC trades compared to contemporaneous quotes on the exchange. Moreover, bilateral OTC trades are cheaper than those intermediated via brokers. In Section 3.1, we define our measure of transaction cost differential, which we label "OTC discount". In Section 3.2, we provide descriptive statistics about the transaction cost measure across trading protocols. Section 3.3 then confirms this result based on a matched sample of bilateral and broker-intermediated trades.

3.1 Definition

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 fraction 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.[8] The denominator in Equation (1) is equal to the quoted half-spread on MTS.

[8] 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 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*.

[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. $price^{\mathrm{MTS}}$ 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 $price^{\mathrm{MTS}}$ 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.

3.2 Properties of OTC Discount

Table 3 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 ("D2D - trade size $\geq$ 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%. Fewer than 16% of D2D trades above 2.5 million EUR incur an OTC premium.

[Table 3 about here.]

The existence of an OTC discount implies that it is typically cheaper for dealers to execute Bund transactions in the over-the-counter market. The difference in transaction costs between OTC 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 35% implies a daily cost advantage of about 2.4 million EUR (600 million EUR annually) from trading OTC rather than on the exchange.[9]

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. $price^{\text{MTS}}$ 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 depth 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 $price^{\text{mid}}$. Both alternative definitions equally give rise to a pervasive and economically large OTC discount.

3.3 Difference in OTC Discount across Protocols

The results documented in the previous section mask sizable differences in the distribution of OTC discount between bilateral and broker OTC trades. As shown in Table 3,

[9] We consider an average half bid-ask spread of four basis points on MTS and a daily trading volume of about 17 billion EUR for this calculation.

bilateral OTC trades ("D2D via bilateral OTC") receive a considerably larger average discount of 54.6% as opposed to 24.6% for brokered trades ("D2D via broker"). 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, i.e. in the majority of cases, trading over-the-counter is cheaper than on the exchange. Moreover, bilateral OTC trades clearly feature more mass on large positive values of OTC discount than broker trades. In summary, a pecking order of average transaction costs emerges: bilateral is cheaper than broker-based OTC trading, and both are cheaper than transactions on the exchange. This is surprising given that 78% of the transaction volume in the D2D segment is executed via brokers, implying that dealers prefer to route the majority of their transactions through a more expensive protocol.

[Figure 2 about here.]

Of course, the OTC discount differential between bilateral and broker-intermediated trades could be due to systematic differences in trade characteristics between the two protocols. For example, as documented above broker trades are often larger in volume than bilateral ones. To fully establish the pecking order of transaction costs, 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.[10] We then estimate the following

[10]The variables used in the matching procedure are: the next 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, informedness, and dummy variables for order splitting, 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. All variables are defined in Section 4. 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.

equation:

$$OTC\ discount_n = \alpha \mathbb{1}_{broker} + \beta' v_n + \varepsilon_n \tag{2}$$

where $\mathbb{1}_{broker}$ indicates a dummy variable that assumes the value one for broker-trades, and where v_n denotes a rich vector of trade-level characteristics. We further include both bond and dealer fixed effects.

[**Table 4 about here.**]

Table 4 shows the results. The main finding is that broker-facilitated trades feature an OTC discount that is about 20 percentage points lower than for bilaterally negotiated trades in the matched sample. While this is somewhat smaller than the difference shown in the summary statistics above, it highlights that broker trades receive a substantially lower OTC discount than similar bilaterally negotiated trades, controlling for a host of potential confounding factors.

4 Information, Protocol Choice and OTC Discount

Our analysis thus far has established a pecking order of transaction costs in the interdealer Bund market. Trades on the exchange are more expensive than OTC trades. Among OTC trades, bilateral trades have lower transaction costs than broker-intermediated OTC trades. These findings are difficult to rationalize with theories relying on 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, however. 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. This section provides empirical evidence supporting this view.

We start by documenting that dealers' choice of trading protocol is often driven by variables measuring the information content of a given trade. We then show that the pecking order of transaction costs is aligned with the informational content of order flows across protocols for predicting Bund returns.

4.1 Protocol Choice in the Interdealer Segment

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.[11] To this end, we estimate a probit model where the dependent variable equals one for over-the-counter trades and zero for trades on MTS. Conditional on a trade not being executed on the exchange, we then estimate a second probit model where the dependent variable equals one for trades via a broker and zero otherwise (i.e., bilaterally negotiated OTC transactions). In both models, the probability to route a trade via a specific protocol depends on a set of proxies for information and search-and-bargaining frictions that we detail next.[12]

4.1.1 Measuring Information and Search-and-Bargaining Frictions

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

Information frictions. 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

[11] We consider the decision of whether to trade on the exchange first because execution there is certain and immediate.

[12] In Appendix D, we conduct a robustness check by considering a multinomial logit model which does not rely on a particular hierarchy of choices. This analysis yields very similar results.

direction (buy or sell) with at most 48 hours between two transactions and without any offsetting trades.

Our second variable measuring information is based on the time elapsed since a dealer last traded the same security, and is similar in spirit to the one used by Brancaccio et al. (2020). The idea is that dealers have more current information about securities they have traded recently. More precisely, *Informedness* is defined as the negative of the logarithm of the time since a dealer last traded the same bond.[13]

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 indicate the direction of orders in the market. *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 information.

In line with information-based theories of hybrid markets, our hypothesis is that more informed transactions are routed via the exchange instead of OTC. Moreover, since the broker protocol provides anonymity, we expect that among all OTC transactions, trades with higher information content are more likely to be broker-intermediated.

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). According to these theories, dealers will transact in the cheapest

[13]The variable is winsorized at the 1 and 99% percentile and its distribution is standardized at the dealer level, see Table A.8 in Appendix E.

protocol. On the exchange, dealers do not face search costs and cannot exercise bargaining power.

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 divided by 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. 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. In line with the theories based on search and bargaining, we expect the probability to trade OTC to depend negatively on both *Inventory* and on *Volatility*.

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 use each dealer's overall trading volume (*Dealer Volume*) as an indirect measure of network centrality (cf. Nikolova, Wang, and Wu, 2020) and, by extension, bargaining power. Our hypothesis is that dealers with a higher overall trading volume are more likely to trade OTC.

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 larger trades become increasingly expensive on MTS, this outside option vanishes with increasing *Trade Size*. Therefore, we expect larger trades to be less likely done via MTS. Moreover, as search costs are likely higher for larger trades and as brokers alleviate search costs, the probability to route an OTC trade via a broker should also increase in trade size.

Appendix E provides detailed definitions of all proxy variables as well as control variables in Table A.8, and their descriptive statistics in Table A.9.

4.1.2 Choice between Exchange and OTC

We study dealers' choice between using the exchange or going OTC via the following probit model:

$$Pr(OTC_n|\omega_{I,n}) = \Phi(\gamma_I' \omega_{I,n}), \tag{3}$$

where Φ is the standard normal cumulative distribution function and $\omega_{I,n}$ is a vector of trade-level proxies for search-and-bargaining and information frictions as well as control variables.

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.[14] Throughout our analysis, all regressors except for dummy variables have been standardized to have mean zero and unit variance.

Specifically, we have:

$$\begin{aligned}\gamma_I' \omega_{I,n} = \gamma_0 &+ \gamma_1 \text{Order Splitting}_n + \gamma_2 \text{Informedness}_n + \gamma_3 \text{Aggregate Order Flow}_n + \\ &+ \gamma_4 \text{Order Book Imbalance}_n + \gamma_5 \text{Inventory}_n + \gamma_6 \text{Volatility}_n + \gamma_7 \text{Dealer Volume}_n \\ &+ \gamma_8 \text{Trade Size 10-30 million EUR}_n + \gamma_9 \text{Trade Size} > 30 \text{ million EUR}_n \\ &+ \gamma_{10} \text{Round Trade Size}_n + \gamma_C \text{Controls}_n\end{aligned} \tag{4}$$

[14]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).

Table 5 provides the regression results. The first three columns show the marginal effects of the probit estimation of Equation (3), with standard errors clustered at the dealer level. We first analyze the role of information frictions in driving protocol choice. Our two measures of private information, order splitting and informedness, point in the same direction: more informed trades are more likely to be routed via MTS. Transactions that have been split into smaller trades are about 2 percentage points more likely to trade on MTS. Moreover, the probability to trade OTC increases by 0.75 to one percentage point with each standard deviation increase in informedness. In contrast to our expectation, we find weakly significant evidence that aggregate market-wide information (aggregate order flow and order book imbalance) increases the probability to trade OTC.

We now turn to the role of search-and-bargaining frictions as drivers of protocol choice. Dealers holding larger inventory of a given security are more likely to transact them OTC. One standard deviation increase in inventory of a given security translates into a 0.66-0.85 percentage points higher probability that the transaction is OTC. 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 about 3 percentage points, in line with the notion that the outside option of search in the OTC market is less feasible.

Finally, larger transactions are less likely to be traded on the exchange. Trades in the 10-30 million EUR range are 1.9 - 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 8.7 - 10.5 percentage points more likely. Round trade sizes are significantly more likely on MTS.

[Table 5 about here.]

In summary, these results show that both information and search-and-bargaining frictions impact dealers' decision to trade on the exchange or in the OTC market. We next study the role of these frictions for the decision to trade bilaterally or via a broker.

4.1.3 Choice between Broker and Bilateral OTC

More than 75% of all interdealer trading is done via brokers. We model dealers' decision to route an OTC trade via a broker or trade bilaterally with the following probit model

$$Pr(Broker_n|OTC_n, \omega_{II,n}) = \Phi(\gamma_{II}' \omega_{II,n}), \tag{5}$$

where $\omega_{II,n}$ captures essentially the same set of trade-level proxies for information and search-and-bargaining frictions as well as trade-level controls. The only difference with respect to the set of explanatory variables $\omega_{I,n}$ used before is that we do not include a dummy for round trade sizes as these are much less prevalent for OTC transactions.

The last three columns of Table 5 show the marginal effects of this probit model. 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 more than 6 percentage points more likely to be routed via a broker. That said, the alternative measure of informedness does not significantly affect the decision to trade 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 about two percentage points. Third, large dealers are more likely to trade via brokers than smaller ones. A dealer with a one standard deviation larger total trading volume is about 14 percent more likely to trade via a broker. 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.

Our interpretation of these results is as follows. Larger and more central dealers as well as dealers with larger trading needs avoid to trade bilaterally and instead prefer to trade anonymously via brokers. Possible motives could be to maintain their informational advantage (Holland, 2001; Babus and Kondor, 2018) or to protect themselves against front-running (Harris, 1997; Brunnermeier and Pedersen, 2005) or back-running (Yang and Zhu, 2020).[15]

In sum, our results suggest that more informed transactions are more likely to take place on the exchange. Among OTC trades more informed transactions are more likely to be routed via an interdealer broker. Combined, they highlight the important role of information frictions in dealers' trading decisions.

4.2 The Informational Content of Order Flows

In the previous section, we have shown that variables measuring the informational content of trades are strong predictors of the protocol in which dealers execute transactions. If there are systematic differences in the informational content of the three trading protocols, these should be reflected in aggregate order flows. Moreover, information is often associated with realized returns. We therefore follow the literature on informed trading in bond markets (e.g. Czech et al., 2021) to assess whether the informational content of trades is in line with the pecking order of transaction costs that we have documented. Specifically, we regress bond returns on order flows in each protocol as follows:

$$\begin{aligned} return_{i,d,d+\Delta} = \; & \gamma_0 + \gamma_1 \text{MTS order flow}_{i,d} + \gamma_2 \text{Broker order flow}_{i,d} \\ & + \gamma_3 \text{Bilateral order flow}_{i,d} \\ & + \gamma_d \Delta_d + \gamma_i \Delta_i + \gamma_C \text{Controls}_n + \varepsilon_{i,d} \,. \end{aligned} \tag{6}$$

Here, $return_{i,d,d+\Delta}$ denotes the cumulative log return of bond i from day d to day $d+\Delta$ in basis points. MTS order flow$_{i,d}$, Broker order flow$_{i,d}$, and Bilateral order flow$_{i,d}$ are the net total volume for each bond and trading day.[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. We also include bond and day fixed effects.

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

[16] We trim returns at the 1st and 99th percentile. Buyer-initiated (seller-initiated) transactions increase (decrease) net order flow. For a bond without any trades in a given day, the order flow is zero. Furthermore, we standardize all variables to have mean zero and variance one. As 30-year Bunds are considerably less often traded than other maturities, we exclude them from this part of our analysis.

[Table 6 about here.]

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

Our findings on the predictive content of order flow are consistent with the pecking order of transaction costs documented in Section 3. Trading on MTS is the most informative about future returns, and also features the highest transaction cost. Trading via brokers has somewhat less predictive power and lower transaction costs. Bilateral trading, in turn, carries no information about future returns and features the lowest transaction costs. These results are also in line with our previous findings that more informed transactions are more likely done on the exchange, and better informed OTC transactions are more likely to be broker-intermediated. Thus information frictions represent a coherent explanation for the observed differences in transaction costs and dealers' protocol choice.

5 Transaction Cost Differentials *within* Protocols

In the previous sections we have established a pecking order of transaction costs which is consistent with informational differences across trading protocols. We now turn to an analysis of the drivers of OTC discount *within* protocols. To this end we regress OTC discount on proxies of information and search-and-bargaining frictions.

5.1 Regression Specification

Transaction costs likely influence dealers' protocol choice. Hence, trading protocol and OTC discount are likely determined jointly. To correct for this potential endogeneity in modeling OTC discount, 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 protocol choice as in Section 4.1. In the second stage we then relate OTC discount to explanatory variables and the inverse Mill's ratio calculated from the first stage.

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 (indexed by n):

$$OTC\ discount_n = \beta_v' v_n + \beta_{\mathrm{OTC}}\hat{\lambda}_n^{\mathrm{OTC}} + \beta_s \hat{\lambda}_n^s + \varepsilon_n, \tag{7}$$

where $s \in \{\text{bilateral}, \text{broker}\}$ indicates the trading protocol used, and where v is a vector collecting proxies for information and search-and-bargaining frictions as well as a set of 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 $\hat{\lambda}^{\text{bilateral}}$ or $\hat{\lambda}^{\text{broker}}$ to control for the decision to trade bilaterally or via a broker, respectively. The explanatory variables in Equation (7) are

$$\begin{aligned} \beta_v' v_n = \ & \beta_0 + \beta_1 \text{Price Impact}_n + \beta_2 \text{Order Splitting}_n + \beta_3 \text{Informedness}_n \\ & + \beta_4 \text{Aggregate Order Flow}_n + \beta_5 \text{Order Book Imbalance}_n \\ & + \beta_6 \text{Inventory}_n + \beta_7 \text{Volatility}_n + \beta_8 \text{Trade Size (log)}_n \\ & + \beta_b \Delta_b + \beta_i \Delta_i + \beta_C \text{Controls}_n \ , \end{aligned} \tag{8}$$

where Δ_b and Δ_i are bond- and initiating dealer fixed effects, respectively, and *Controls* is a vector of further control variables as above.[17] As an additional proxy for information frictions we now also include *Price impact* as the price change 15 minutes after each trade, following Collin-Dufresne et al. (2020).[18] We interpret trades with larger price impact as being more informed.

[17]Specifically, *Controls* accounts 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.

[18]Price impact captures the ex-post reaction of MTS prices to trades. This reaction is structurally different across protocols. For example, when an exchange trade depletes levels of the order book, it immediately shifts prices even without a reaction from other market participants adjusting their limit orders. This is not the case for OTC transactions. For this reason, and to avoid a potential endogeneity bias, we do not include price impact in our protocol choice estimations above.

5.2 Estimation Results

Table 7 shows the estimation results, with standard errors obtained via bootstrap to account for correlation with protocol choice.[19]

[Table 7 about here.]

Bilaterally Negotiated Interdealer Trading Column (1) of Table 7 reports the coefficient estimates for bilaterally negotiated OTC trades. A one-standard deviation increase in price impact is associated with a 2.2 percentage points lower OTC discount. Order splitting has a similarly large effect, which, however, is not statistically significant.[20] We also do not find a statistically significant impact of informedness in the presence of the above two proxies for private information. The coefficient for aggregate order flow is negative and highly significant, implying that trades in the same direction as the overall market feature a lower OTC discount. These results suggest that dealers, at least to some extent, price discriminate against each other based on their counterparty's perceived information.

We next turn to the role of search-and-bargaining frictions. Volatility, which makes the outside option of continued search more costly or less feasible, strongly raises transaction costs. A one-standard deviation increase in volatility reduces OTC discount by about 10 percentage points. OTC discount also decreases with trade size. A one standard deviation larger trade is associated with a 4.2 percentage points lower OTC discount.[21] Importantly, our regression includes dealer fixed effects which absorb any residual time-invariant differences in bargaining power across dealers. The estimated fixed effects show

[19]Specifically, we draw 1,000 samples 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 step.

[20]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.

[21]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), Pinter, Wang, and Zou (2023) show that after controlling for trader fixed effects transaction costs increase with size, in line with our setup and result. An and Song (2020) document a similar trade-size markup effect for Federal Reserve purchases of agency MBS.

sizeable variation: the standard deviation across dealers amounts to 17.6 percentage points of the MTS half-spread – almost one third of the average OTC discount.

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 7. In column (2) we repeat the estimation including these dummies instead of dealer-fixed effects. The top five dealers receive a 7.5 percentage points higher OTC discount, whereas the bottom five obtain a 18.3 percentage points lower OTC discount relative to their peers. These effects are again sizeable in light of the average OTC discount of 54.6 percent. This suggests that dealer-specific bargaining power plays a quantitatively important role for transaction cost, over and above the proxies included in our regressions.

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 the determinants of OTC Discount for trades intermediated by interdealer brokers. Column (3) in Table 7 shows the results. They highlight that the same set of drivers as for bilateral OTC trades affects transaction costs in the broker protocol.

Specifically, we find that higher price impact and the presence of order splitting are both associated with significantly lower OTC discounts. While the coefficient on price impact is somewhat smaller compared to bilateral trades, the order splitting dummy is highly significant and almost twice as large. Trades that are part of a meta order receive a discount that is 4.2 percentage points lower. While the coefficient on informedness is negative as expected, it is not statistically significant. Trading in the same direction as the market also significantly reduces OTC discount. A one-standard deviation higher aggregate order flow implies a 1.5 percentage points lower OTC discount for broker-facilitated trades.

We now turn to measures of search-and-bargaining frictions. As before, days with higher volatility are characterized by substantially lower OTC discounts. The impact of volatility is about 50% larger than for bilateral trades and highly statistically significant. As for bilateral transactions, larger trades receive significantly smaller discounts. A one-standard deviation increase in log trade size is associated with a 3.2 percentage points lower OTC discount.

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 discounts, consistent with search-and-bargaining-based theories of OTC markets. While the coefficients differ slightly, the role of information and search-and-bargaining frictions is comparable across the two OTC protocols.

5.3 The Dealer-to-Customer Segment

While our paper focuses on the hybrid market structure of the Bund interdealer segments 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 F, 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 transaction cost 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.

6 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. Using a unique regulatory dataset of securities transactions, our paper contributes to this debate along several dimensions. 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, giving rise to a pecking order of transaction costs. Dealers' decisions where to execute a trade depend both on their bargaining power as well as on the information they have. Consistently, we document that this pecking order is in line 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 present in hybrid markets.

Our findings are relevant for the growing literature on OTC markets. Specifically, they suggest that both theoretical and empirical work in this area should strive to account for the complex structure of today's markets by considering: (i) the coexistence of multiple trading protocols, (ii) the relevance of interdealer brokers, (iii) the importance of both information and search-and-bargaining frictions, and (iv) the interlinkages between the interdealer and the D2C segment.

On the regulatory side, there is a strong effort to improve OTC market functioning. In Europe the MiFID II regulation was rolled out with the intention to improve market transparency, while in the U.S. FINRA has started to collect transaction-level data for sovereign bonds similar to that in the TRACE database and the regulatory dataset used in this paper. In recent years there has also been a regulatory push away from OTC towards exchange-based trading. However, as pointed out by Dugast et al. (2022), a centralized exchange market is not always socially optimal, as agents' trading decisions are driven by their private incentives. While our empirical analysis cannot shed light on the socially optimal market structure, our results suggest that there is substantial heterogeneity across trades and dealers. As a result, bilateral, broker-intermediated and exchange-based trading protocols all play complementary roles in serving the different needs of dealers in a way that a single venue might not be able to achieve.

References

Allen, J. and M. Wittwer (2023). Centralizing over-the-counter markets? *Journal of Political Economy 131*(12), 3310–3351.

Amihud, Y. and H. Mendelson (1980). Dealership market: Market-making with inventory. *Journal of Financial Economics 8*(1), 31–53.

An, Y. and Z. Song (2020). Does the federal reserve obtain competitive and appropriate prices in monetary policy implementations? *Johns Hopkins Carey Business School Research Paper No. 20-05*.

Anderson, C. and W. Liu (2023). Inferring intermediary risk exposure from trade. *Management Science*. forthcoming.

Babus, A. and P. Kondor (2018). Trading and information diffusion in over-the-counter markets. *Econometrica 86*(5), 1727–1769.

Babus, A. and C. Parlatore (2022). Strategic fragmented markets. *Journal of Financial Economics 145*(3), 876–908.

Barbon, A., M. Di Maggio, F. Franzoni, and A. Landier (2019). Brokers and order flow leakage: Evidence from fire sales. *The Journal of Finance 74*(6), 2707–2749.

Barclay, M. J., T. Hendershott, and K. Kotz (2006). Automation versus intermediation: Evidence from treasuries going off the run. *The Journal of Finance 61*(5), 2395–2414.

Berger-Soucy, L., C. Garriott, and A. Usche (2018). Government of Canada fixed-income market ecology. *Bank of Canada Staff Discussion Paper 2018-10*.

Bessembinder, H., C. Spatt, and K. Venkataraman (2020). A survey of the microstructure of fixed-income markets. *Journal of Financial and Quantitative Analysis 55*(1), 1–45.

Bessembinder, H. and K. Venkataraman (2004). Does an electronic stock exchange need an upstairs market? *Journal of Financial Economics 73*(1), 3–36.

Brancaccio, G., D. Li, and N. Schürhoff (2020). Learning by trading: The case of the US market for municipal bonds. *Mimeo*.

Brunnermeier, M. K. and L. H. Pedersen (2005). Predatory trading. *The Journal of Finance 60*(4), 1825–1863.

Burdett, K. and M. O'Hara (1987). Building blocks: An introduction to block trading. *Journal of Banking & Finance 11*(2), 193–212.

Cenedese, G., A. Ranaldo, and M. Vasios (2020). OTC premia. *Journal of Financial Economics 136*(1), 86–105.

Chowdhry, B. and V. Nanda (1991). Multimarket trading and market liquidity. *The Review of Financial Studies 4*(3), 483–511.

Colliard, J.-E. and G. Demange (2021). Asset dissemination through dealer markets. *Management Science 67*(10), 6211–6234.

Colliard, J.-E., T. Foucault, and P. Hoffmann (2021). Inventory management, dealers' connections, and prices in over-the-counter markets. *The Journal of Finance 76*(5), 2199–2247.

Collin-Dufresne, P., B. Junge, and A. B. Trolle (2020). Market structure and transaction costs of index cdss. *The Journal of Finance 75*(5), 2719–2763.

Copeland, A., M. J. Fleming, F. M. Keane, and R. Mithal (2018). Do you know how your Treasury trades are cleared and settled? *Federal Reserve Bank of New York Liberty Street Economics Blog*.

Czech, R., S. Huang, D. Lou, and T. Wang (2021). Informed trading in the government bond market. *Journal of Financial Economics 142*(3), 1253–1274.

Darbha, M. and A. Dufour (2013). Microstructure of the Euro-area government bond market. In H. K. Baker and H. Kiymaz (Eds.), *Market Microstructure in Emerging and Developed Markets*, Chapter 3, pp. 39–58. Wiley Online Library.

Di Maggio, M., F. Franzoni, A. Kermani, and C. Sommavilla (2019). The relevance of broker networks for information diffusion in the stock market. *Journal of Financial Economics 134*(2), 419–446.

Di Maggio, M., A. Kermani, and Z. Song (2017). The value of trading relations in turbulent times. *Journal of Financial Economics 124*(2), 266–284.

Dick-Nielsen, J. and M. Rossi (2019). The cost of immediacy for corporate bonds. *The Review of Financial Studies 32*(1), 1–41.

Duffie, D. (2012). *Dark markets: Asset pricing and information transmission in over-the-counter markets*. Princeton University Press.

Duffie, D., N. Gârleanu, and L. H. Pedersen (2005). Over-the-counter markets. *Econometrica 73*(6), 1815–1847.

Duffie, D., N. Gârleanu, and L. H. Pedersen (2007). Valuation in over-the-counter markets. *The Review of Financial Studies 20*(6), 1865–1900.

Duffie, D. and H. Zhu (2017). Size discovery. *The Review of Financial Studies 30*(4), 1095–1150.

Dufour, A. and F. Skinner (2004). MTS time series: Market and data description for the European bond and repo database. Technical report, Henley Business School, Reading University.

Dugast, J., S. Üslü, and P.-O. Weill (2022). A theory of participation in OTC and centralized markets. *The Review of Economic Studies 89*(6), 3223–3266.

Dunne, P. G., H. Hau, and M. J. Moore (2015). Dealer intermediation between markets. *Journal of the European Economic Association 13*(5), 770–804.

Edwards, A. K., L. E. Harris, and M. S. Piwowar (2007). Corporate bond market transaction costs and transparency. *The Journal of Finance 62*(3), 1421–1451.

Fleming, M. J. (1997). The round-the-clock market for U.S. Treasury securities. *Economic Policy Review 3*(2).

Fleming, M. J. and G. Nguyen (2019). Price and size discovery in financial markets: Evidence from the US Treasury securities market. *The Review of Asset Pricing Studies 9*(2), 256–295.

Fleming, M. J. and E. M. Remolona (1999). Price formation and liquidity in the U.S. Treasury market: The response to public information. *The Journal of Finance 54*(5), 1901–1915.

Friewald, N. and F. Nagler (2019). Over-the-counter market frictions and yield spread changes. *The Journal of Finance 74*(6), 3217–3257.

Glode, V. and C. C. Opp (2020). Over-the-counter versus limit-order markets: The role of traders' expertise. *The Review of Financial Studies 33*(2), 866–915.

Goldstein, M. A. and E. S. Hotchkiss (2020). Providing liquidity in an illiquid market: Dealer behavior in US corporate bonds. *Journal of Financial Economics 135*(1), 16–40.

Green, R. C., B. Hollifield, and N. Schürhoff (2007). Financial intermediation and the costs of trading in an opaque market. *The Review of Financial Studies 20*(2), 275–314.

Grossman, S. J. (1992). The informational role of upstairs and downstairs trading. *Journal of Business*, 509–528.

Gündüz, Y., L. Pelizzon, M. Schneider, and M. G. Subrahmanyam (2023). Lighting up the dark: liquidity in the German corporate bond market. *Journal of Fixed Income*. forthcoming.

Hagströmer, B. and A. J. Menkveld (2019). Information revelation in decentralized markets. *The Journal of Finance 74*(6), 2751–2787.

Han, M., S. H. Kim, and V. K. Nanda (2023). Institutional brokerage networks: Facilitating liquidity provision. *Review of Financial Studies*. forthcoming.

Harris, L. (1997). Order exposure and parasitic traders. *University of Southern California working paper*.

Hau, H., P. Hoffmann, S. Langfield, and Y. Timmer (2021). Discriminatory pricing of over-the-counter derivatives. *Management Science 67*(11), 6660–6677.

Hendershott, T., D. Li, D. Livdan, and N. Schürhoff (2020). Relationship trading in over-the-counter markets. *The Journal of Finance 75*(2), 683–734.

Hendershott, T. and A. Madhavan (2015). Click or call? Auction versus search in the over-the-counter market. *The Journal of Finance 70*(1), 419–447.

Holden, C. W., D. Lu, V. Lugovskyy, and D. Puzzello (2021). What is the impact of introducing a parallel OTC market? theory and evidence from the chinese interbank fx market. *Journal of Financial Economics 140*(1), 270–291.

Holland, A. (2001). The development of alternative trading systems in the UK gilt market: lessons and implications. *Financial Market Structure and Dynamics Conference at the Bank of Canada*.

Hollifield, B., A. Neklyudov, and C. Spatt (2017). Bid-ask spreads, trading networks, and the pricing of securitizations. *The Review of Financial Studies 30*(9), 3048–3085.

Hugonnier, J., B. Lester, and P.-O. Weill (2022). Heterogeneity in decentralized asset markets. *Theoretical Economics 17*(3), 1313–1356.

Kondor, P. and G. Pinter (2022). Clients' connections: Measuring the role of private information in decentralized markets. *The Journal of Finance 77*(1), 505–544.

Lee, C. M. and M. J. Ready (1991). Inferring trade direction from intraday data. *The Journal of Finance 46*(2), 733–746.

Lee, T. and C. Wang (2023). Why trade over-the-counter? *The Journal of Finance*. forthcoming.

Li, D. and N. Schürhoff (2019). Dealer networks. *The Journal of Finance 74*(1), 91–144.

MacKenzie, D., I. Hardie, C. Rommerskirchen, and A. van der Heide (2020). Why hasn't high-frequency trading swept the board? shares, sovereign bonds and the politics of market structure. *Review of International Political Economy*, 1–25.

Madhavan, A. and M. Cheng (1997). In search of liquidity: Block trades in the upstairs and downstairs markets. *The Review of Financial Studies 10*(1), 175–203.

Meling, T. G. (2021). Anonymous trading in equities. *The Journal of Finance 76*(2), 707–754.

Menkveld, A. J., B. Z. Yueshen, and H. Zhu (2017). Shades of darkness: A pecking order of trading venues. *Journal of Financial Economics 124*(3), 503–534.

Mizrach, B. and C. J. Neely (2009). The microstructure of the U.S. Treasury market. In *The Encyclopedia of Complexity and System Science*.

Nikolova, S., L. Wang, and J. J. Wu (2020). Institutional allocations in the primary market for corporate bonds. *Journal of Financial Economics 137*(2), 470–490.

O'Hara, M. and X. A. Zhou (2021). The electronic evolution of corporate bond dealers. *Journal of Financial Economics 140*(2), 368–390.

Pagano, M. (1989). Trading volume and asset liquidity. *The Quarterly Journal of Economics 104*(2), 255–274.

Pinter, G., C. Wang, and J. Zou (2022). Information chasing versus adverse selection in over-the-counter markets. *Bank of England Working Paper No. 971*.

Pinter, G., C. Wang, and J. Zou (2023). Size discount and size penalty: Trading costs in bond markets. *Review of Financial Studies*. forthcoming.

Ranaldo, A. and F. Somogyi (2021). Asymmetric information risk in fx markets. *Journal of Financial Economics 140*(2), 391–411.

Riggs, L., E. Onur, D. Reiffen, and H. Zhu (2020). Swap trading after Dodd-Frank: Evidence from index CDS. *Journal of Financial Economics 137*(3), 857–886.

Seppi, D. J. (1990). Equilibrium block trading and asymmetric information. *The Journal of Finance 45*(1), 73–94.

Stoll, H. R. (1978). The supply of dealer services in securities markets. *The Journal of Finance 33*(4), 1133–1151.

Üslü, S. (2019). Pricing and liquidity in decentralized asset markets. *Econometrica 87*(6), 2079–2140.

Vogel, S. (2019). When to introduce electronic trading platforms in over-the-counter markets? *Mimeo*.

Yang, L. and H. Zhu (2020). Back-running: Seeking and hiding fundamental information in order flows. *The Review of Financial Studies 33*(4), 1484–1533.

Yoon, J. H. (2019). Endogenous market structure: Over-the-counter versus exchange trading. *Mimeo*.

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 fraction 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.

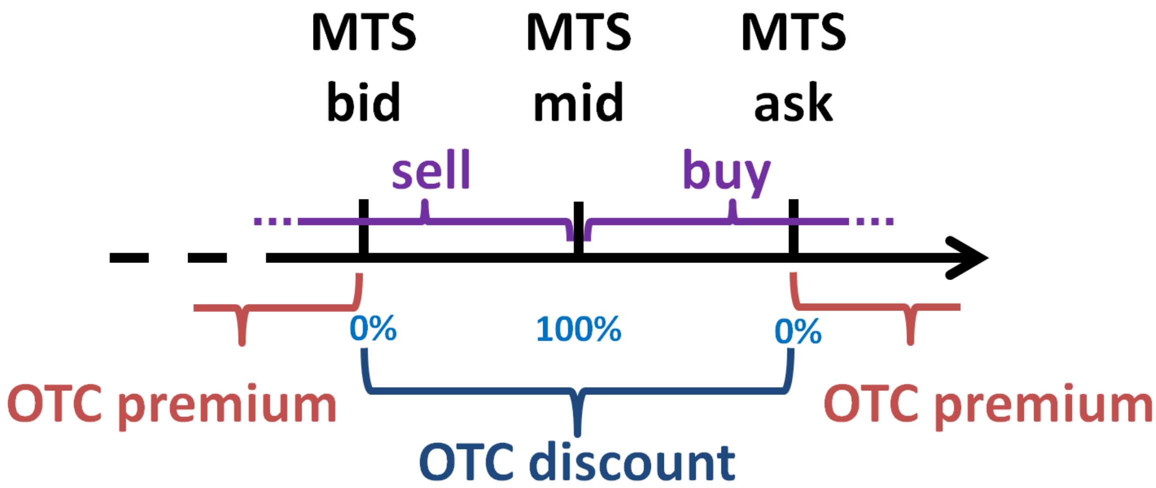
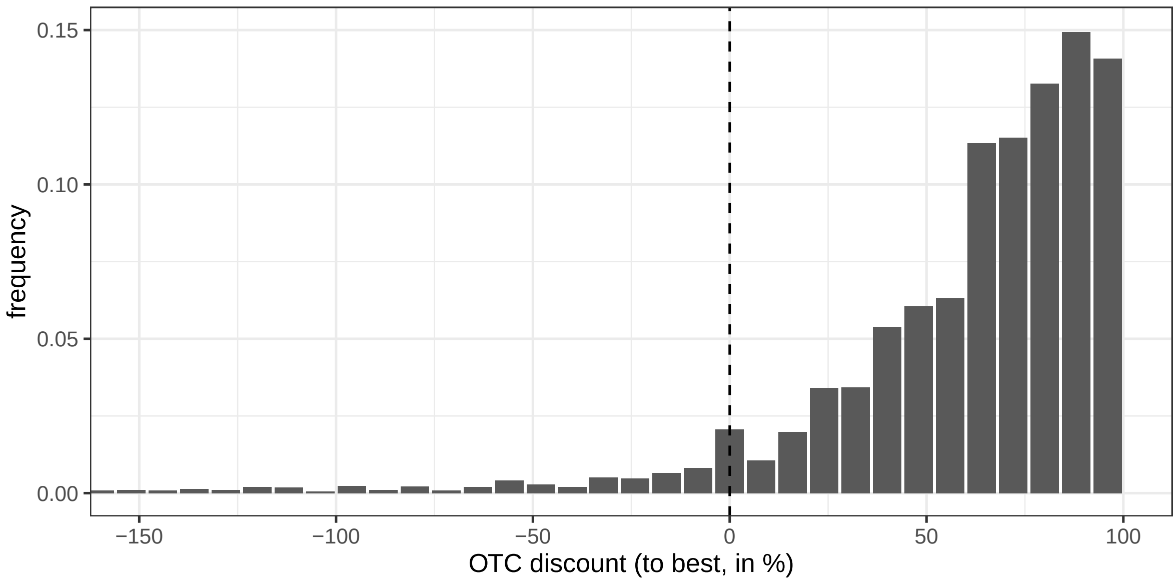
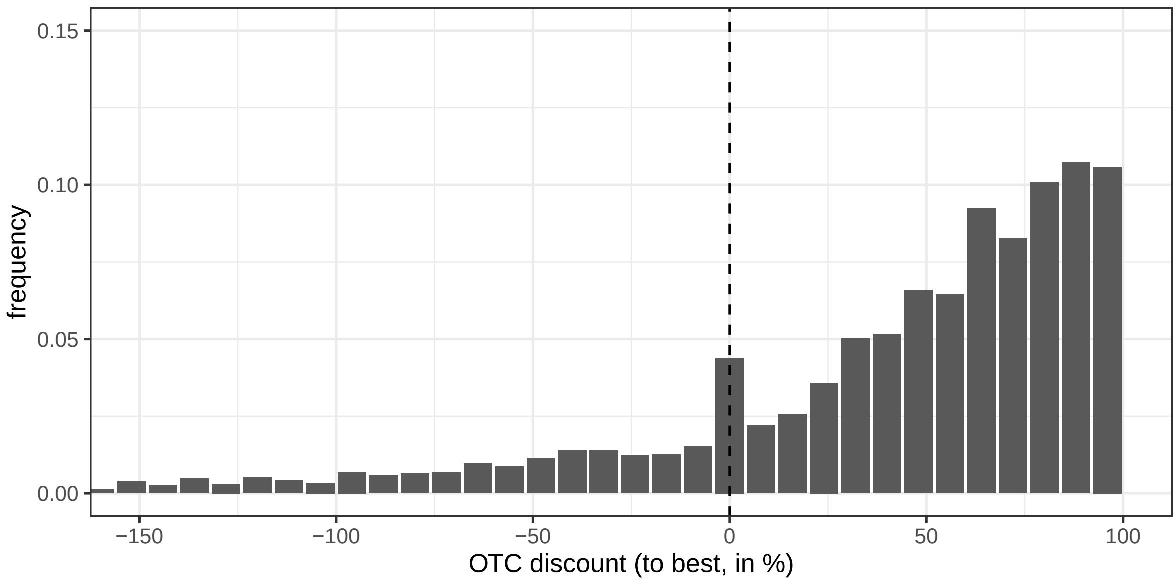


Figure 2. Histogram of OTC Discount: *OTC discount* is defined in Equation (1) in Section 3.1. For a buyer-initiated trade OTC discount is the price difference between the quoted best ask price on MTS and the observed price of the trade, measured as a fraction of the MTS half-spread, that is, the difference 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. 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. Comparison of Trading Characteristics across Protocols: This Table summarizes the characteristics of the trading protocols used in the interdealer Bund market. Pre-trade transparency refers to the observability of trading conditions before a trade takes place, e.g. through the dissemination of order book information. Post-trade transparency implies the disclosure of information on trades after a trade took place. We refer to anonymity when counterparties of the transaction or other market participants do not observe the identity of the participants involved in the transaction. Immediacy implies fast and certain execution of trades.

		Exchange	OTC	
			Bilateral	Broker
Transparency				
pre-trade		Yes	No	No
post-trade		Yes	No	No
Anonymity				
pre-trade	all participants	Yes	Yes	Yes
	involved counterparties	Yes	No	Yes
post-trade	all participants	Yes	Yes	Yes
	involved counterparties	No	No	Yes
Immediacy		Yes	No	No

Table 2. 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*, 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	13,282	366.43	77.94	27.59	27.09	3.00	7.00	20.00	40.00	85.00

Table 3. Descriptive Statistics of OTC Discount: *OTC discount* is defined in Equation (1) in Section 3.1. 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 fraction 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. 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 2, 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	13,226	24.60	96.44	-160.47	9.52	55.50	80.00	95.65	20.4	0.0000

Table 4. Differences in OTC Discount across Interdealer Protocols: OLS estimation of $OTC\ discount_n = \beta' v_n + \varepsilon_n$ (see Equation (2) and Section 3.3). The dependent variable, OTC discount, defined in Equation (1) in Section 3.1, is 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 fraction of the hypothetical transaction cost on the exchange. 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 3.3. 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)	-20.2928***	-18.9691***
	(-6.0892)	(-4.9009)
Price impact (15min)		-0.9012
		(-1.5610)
Order splitting (dummy)		-2.5828
		(-1.0046)
Informedness		-0.2375
		(-0.2830)
Aggregate order flow		-0.8898
		(-1.0172)
Order book imbalance		0.2541
		(0.5530)
Inventory		-0.1927
		(-0.1543)
Volatility		-12.8433***
		(-7.0713)
Trade size (log)		-1.5569
		(-0.4594)
Intercept	55.2786***	55.1914***
	(33.1345)	(26.3025)
R^2	0.1223	0.1907
R^2_{adjusted}	0.0987	0.1657
R^2_{within}	0.0400	0.1148
N	4,317	4,317
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table 5. Probability Model for Protocol Choice: Marginal effects at means of a probit model. In specifications (1) - (3) 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 transaction n takes place OTC, and zero when it is on MTS. In specifications (4) - (6) 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 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 information and search-and-bargaining frictions as detailed in Equation (4), cf. section 4.1.2. 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)	(3)	(4)	(5)	(6)
Order splitting (dummy)	-0.0232***		-0.0197***	0.0664***		0.0647***
	(-3.7038)		(-3.1317)	(3.8505)		(2.7181)
Informedness		-0.0119***	-0.0075***		-0.0001	-0.0125
		(-6.1722)	(-3.5398)		(-0.0105)	(-1.0042)
Aggregate order flow	0.0050*	0.0050*	0.0050*	0.0102	0.0111	0.0098
	(1.8605)	(1.8724)	(1.8995)	(1.0530)	(1.1435)	(1.0267)
Order book imbalance	0.0032*	0.0029	0.0027	-0.0058**	-0.0042	-0.0045
	(1.7368)	(1.5727)	(1.5117)	(-2.0911)	(-1.4078)	(-1.5412)
Inventory	0.0085***	0.0066***	0.0066***	0.0217***	0.0193***	0.0193***
	(3.2592)	(3.0344)	(3.0054)	(3.1044)	(2.6956)	(2.7077)
Volatility	-0.0331***	-0.0290***	-0.0290***	-0.0040	0.0002	0.0001
	(-7.5524)	(-7.7091)	(-7.7118)	(-0.3978)	(0.0240)	(0.0121)
Dealer Volume	-0.0177	-0.0192	-0.0185	0.1416***	0.1339***	0.1326***
	(-0.8827)	(-1.0488)	(-1.0078)	(2.7134)	(2.6322)	(2.6192)
Trade size 10-30 million EUR (dummy)	0.0262**	0.0191*	0.0200*	0.2095***	0.2080***	0.2036***
	(2.3568)	(1.6539)	(1.7396)	(4.1278)	(4.0368)	(3.9766)
Trade size > 30 million EUR (dummy)	0.1035***	0.0870***	0.0890***	0.3671***	0.3684***	0.3602***
	(3.8109)	(3.3454)	(3.3510)	(7.7604)	(7.6409)	(7.5038)
Round trade size (2.5/5/10 mn EUR, dummy)	-0.1688***	-0.1523***	-0.1508***			
	(-9.3607)	(-8.1698)	(-8.2199)			
R^2_{pseudo}	0.4110	0.4073	0.4093	0.1854	0.1858	0.1886
N	21,787	20,242	20,242	19,691	18,546	18,546
Controls	yes	yes	yes	yes	yes	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 (6) and Section 4.2). 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

Table 7. 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 (7) and Section 5.1). The dependent variable, OTC discount, defined in Equation (1) in Section 3.1, is 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 fraction of the hypothetical transaction cost on the exchange. v_n, as detailed in Equation (8), is a vector of variables representing information and search-and-bargaining frictions, fixed effects for bond and initiating dealer, and a set of control variables. These include the 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 variables for end-of-quarter days or end-of-year days. λ^{OTC} and λ^{s}, s $\in \{bilateral, broker\}$, are the Inverse Mills ratios controlling for protocol choice. The sample consists of bilaterally negotiated OTC trades between dealers in specifications (1) and (2) (row *D2D via bilateral OTC* in Table 2) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker* in Table 2). 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)	-2.2285***	-2.2508***	-1.3561**
	(-3.2367)	(-3.2653)	(-2.4922)
Order splitting (dummy)	-2.1973	-2.6248*	-4.1521***
	(-1.3577)	(-1.7040)	(-3.1084)
Informedness	-0.3288	-0.3476	-0.1769
	(-0.5334)	(-0.5730)	(-0.3222)
Aggregate order flow	-1.7390***	-1.7630***	-1.4726***
	(-3.7491)	(-3.8898)	(-3.1311)
Order book imbalance	-0.6214	-0.5714	0.1480
	(-1.1937)	(-1.1137)	(0.2817)
Inventory	-0.7140	-0.7903	-0.4154
	(-1.2631)	(-1.5358)	(-0.7993)
Volatility	-10.2794***	-10.3751***	-15.9561***
	(-8.2978)	(-8.4067)	(-14.5200)
Trade size (log)	-4.1577***	-4.9888***	-3.1803***
	(-3.2199)	(-6.0573)	(-2.8536)
Top 5 dealer (dummy)		7.4927***	
		(5.9132)	
Bottom 5 dealer (dummy)		-18.3482***	
		(-5.7457)	
Inv. Mills OTC	-0.2614	-0.1349	0.3912
	(-0.4630)	(-0.2397)	(0.7183)
Inv. Mills bilateral	1.4963	0.2821	
	(0.9721)	(0.3288)	
Inv. Mills broker			-5.9684***
			(-4.0760)
Intercept	59.8610***	59.7788***	37.4653***
	(79.1175)	(74.8237)	(43.3042)
R^2	0.1344	0.1310	0.2161
R^2_{adjusted}	0.1106	0.1115	0.2069
R^2_{within}	0.0799	0.0970	0.0772
N	5,871	5,871	12,179
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Appendix

accompanying

OTC Discount

January 19, 2024

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.[22] 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.[23]

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.[24] 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

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

[23]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/`.

[24]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.[25] Broker fees are of the order of 0.15 basis points.[26]

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.[27]

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

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

[27]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.[28] Gündüz, Pelizzon, Schneider, and Subrahmanyam (2023) 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.[29]

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

[28] 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`.

[29] 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 3.1) 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.[30]

[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 3). 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 (where transaction cost 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.]

In Table A.2 we present the results of regressing the alternative definition of OTC discount on the matched sample described in Section 3.3. A dummy for broker trades in the regression captures the difference in OTC discount between otherwise similar bilateral and

[30]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.

broker OTC trades. We find that broker trades feature, on average, $17.1 - 17.8$ 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 $19.0 - 20.3$ percentage points difference obtained in Section 3.3 and Table 4, confirming the robustness of our results to size effects.

[Table A.3 about here.]

Table A.3 presents the results of estimating Equation (7) with OTC discount as re-defined above as the dependent variable. Most results are similar to those presented in the main text and Table 7. That is, more informed trades receive lower discounts, and OTC discount is also smaller on more volatile days. 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.

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 measured as a share of price on the matched sample described in Section 3.3. We find that trades via brokers receive, on average, $0.62 - 0.77$ basis points (of mid-price) less discount than comparable bilateral OTC trades, in line with our previous findings.

[Table A.6 about here.]

Table A.6 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 5.2 and Table 7. The estimation results are in line with our previous findings, but since our definition of OTC discount has changed the magnitude of the estimated coefficients is different. 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.

D Multinomial Protocol Choice Model

In Section 5.1 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.7, are in line with those in the main text of the paper.

[Table A.7 about here.]

E Descriptive Statistics of Explanatory Variables

In Table A.8 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.9 presents descriptive statistics of the explanatory variables. We distinguish for the samples defined in Table 2 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.

[Tables A.8 and A.9 about here.]

F 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 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 in our sample. In addition there are a few electronic platforms which are either 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.10 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.10. A comparison of the cross-sectional distributions of the latter two subsamples suggests that there are only minor differences in terms of trade size.

[**Table A.10 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.10, 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 (7) for bilateral interdealer trades (specification (1) of Table 7). 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.11 about here.]

Table A.11 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.11 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. (2022) and Kondor and Pinter (2022).

Our results are robust to lowering 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.

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 2, 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	13,226	46.59	70.63	-91.42	36.15	69.59	87.18	97.67	13.2	0.0000

Table A.2. 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 (2) and Section 3.3). 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 3.3. 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)	-17.0528***	-17.8269***
	(-5.9344)	(-5.8481)
Price impact (15min)		-0.7655
		(-1.5262)
Order splitting (dummy)		-2.1645
		(-0.9925)
Informedness		0.1478
		(0.1819)
Aggregate order flow		-0.5466
		(-0.6864)
Order book imbalance		0.4165
		(1.1637)
Inventory		-0.1957
		(-0.1852)
Volatility		-12.0845***
		(-6.9823)
Trade size (log)		8.1988**
		(3.0242)
Intercept	62.1390***	62.9088***
	(42.6106)	(39.5652)
R^2	0.1153	0.1947
R^2_{adjusted}	0.0915	0.1698
R^2_{within}	0.0335	0.1202
N	4,317	4,317
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table A.3. Intermediation Frictions and OTC Discount: with walking up the book. OLS estimation of $OTC\ discount_n = \gamma' v_n + \gamma_{\mathrm{OTC}}\lambda_n^{\mathrm{OTC}} + \gamma_s \lambda_n^s + \varepsilon_n$ (cf. Equation (7) and Section 5.2). 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 (8), 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 2) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker* in Table 2). 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)	-1.9988***	-1.9940***	-1.0713**
	(-3.0428)	(-3.0179)	(-2.1236)
Order splitting (dummy)	-3.1757**	-3.5350**	-2.2784**
	(-2.1306)	(-2.5060)	(-2.0212)
Informedness	0.1084	0.1301	-0.2876
	(0.1872)	(0.2290)	(-0.6048)
Aggregate order flow	-1.8706***	-1.8949***	-0.9888**
	(-4.4357)	(-4.5963)	(-2.4415)
Order book imbalance	-0.4731	-0.4610	0.4784
	(-0.9758)	(-0.9637)	(1.0676)
Inventory	-0.8258	-0.7908	0.1183
	(-1.5661)	(-1.6332)	(0.2579)
Volatility	-9.8351***	-9.8817***	-13.6026***
	(-8.1504)	(-8.2401)	(-13.4341)
Trade size (log)	2.0563*	1.7116**	11.6989***
	(1.8362)	(2.4622)	(12.2492)
Top 5 dealer (dummy)		6.2833***	
		(5.6433)	
Bottom 5 dealer (dummy)		-15.6302***	
		(-5.4278)	
Inv. Mills OTC	-0.9738*	-0.9025*	0.5738
	(-1.7823)	(-1.6545)	(1.1432)
Inv. Mills bilateral	-0.0871	-0.5218	
	(-0.0630)	(-0.6679)	
Inv. Mills broker			-1.6855
			(-1.2853)
Intercept	65.2067***	64.9872***	51.5580***
	(94.7594)	(88.7918)	(69.3699)
R^2	0.1142	0.1111	0.2467
R^2_{adjusted}	0.0898	0.0911	0.2378
R^2_{within}	0.0604	0.0729	0.1058
N	5,871	5,871	12,179
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	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 2, 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	13,226	1.59	4.70	-4.39	0.17	1.20	2.42	11.02	20.4	0.0000

Table A.5. Differences in OTC Discount across Interdealer Protocols: normalized by price. OLS estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ (cf. Equation (2) and Section 3.3). 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 3.3. 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)	-0.7718***	-0.6172*
	(-4.4330)	(-2.5343)
Price impact (15min)		-0.1720
		(-1.8374)
Order splitting (dummy)		-0.0565
		(-0.4173)
Informedness		-0.0239
		(-0.3034)
Aggregate order flow		-0.0542
		(-0.9771)
Order book imbalance		0.0691
		(0.8217)
Inventory		0.0085
		(0.1235)
Volatility		-1.1468***
		(-4.0843)
Trade size (log)		-0.1986
		(-0.8701)
Intercept	1.8371***	1.6927***
	(23.3258)	(11.6042)
R^2	0.2219	0.4001
R^2_{adjusted}	0.2010	0.3817
R^2_{within}	0.0121	0.2384
N	4,317	4,317
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table A.6. 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 (7) and Section 5.2). 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 (8), 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 2) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker* in Table 2). 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)	-0.1974**	-0.1992**	-0.1169
	(-2.3400)	(-2.3682)	(-1.6328)
Order splitting (dummy)	-0.1851*	-0.1804*	-0.1813*
	(-1.7783)	(-1.8722)	(-1.8788)
Informedness	-0.0251	-0.0266	0.0204
	(-0.5523)	(-0.5799)	(0.5380)
Aggregate order flow	-0.0438	-0.0358	-0.0216
	(-1.5067)	(-1.3060)	(-0.6395)
Order book imbalance	0.0009	0.0008	-0.0008
	(0.0275)	(0.0236)	(-0.0309)
Inventory	-0.0225	-0.0128	-0.0896**
	(-0.6174)	(-0.4151)	(-2.2874)
Volatility	-0.8668***	-0.8801***	-1.5107***
	(-4.6935)	(-4.7815)	(-10.8842)
Trade size (log)	-0.3529***	-0.3015***	-0.1935**
	(-2.9858)	(-4.7012)	(-2.3129)
Top 5 dealer (dummy)		0.3242***	
		(3.6794)	
Bottom 5 dealer (dummy)		-1.0239***	
		(-3.7178)	
Inv. Mills OTC	0.0597	0.0625*	0.0529
	(1.5737)	(1.6725)	(1.3090)
Inv. Mills bilateral	0.0561	0.0956	
	(0.4212)	(1.3944)	
Inv. Mills broker			-0.3378***
			(-3.1433)
Intercept	2.0669***	2.0953***	1.6628***
	(32.3491)	(32.5443)	(24.1027)
R^2	0.4810	0.4792	0.4451
R^2_{adjusted}	0.4668	0.4675	0.4385
R^2_{within}	0.2705	0.2781	0.2084
N	5,871	5,871	12,179
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Table A.7. 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 D. 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* in Table 2. 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)	0.0200***	-0.0705***	0.0505**
	(3.1047)	(-3.0512)	(2.3992)
Informedness	0.0070***	0.0044	-0.0114
	(3.0063)	(0.4004)	(-0.9840)
Aggregate order flow	-0.0056**	-0.0075	0.0131
	(-2.1166)	(-0.8082)	(1.4870)
Order book imbalance	-0.0025	0.0035	-0.0010
	(-1.3204)	(1.0350)	(-0.3191)
Inventory	-0.0064***	-0.0145**	0.0209***
	(-2.7460)	(-2.2120)	(3.3755)
Volatility	0.0302***	-0.0176	-0.0126
	(8.6619)	(-1.6381)	(-1.1815)
Dealer Volume	0.0168	-0.1276***	0.1108**
	(0.9305)	(-2.5781)	(2.2659)
Trade size 10-30 million EUR (dummy)	-0.0160	-0.1772***	0.1932***
	(-1.5967)	(-3.7808)	(4.3456)
Trade size gt 30 million EUR (dummy)	-0.0831**	-0.2785***	0.3616***
	(-2.5266)	(-5.5157)	(8.6470)
Round trade size (2.5/5/10 mn EUR, dummy)	0.1518***	0.0195	-0.1713***
	(8.8193)	(0.7663)	(-6.5737)
R^2_{pseudo}		0.2662	
N		20,242	
Controls		yes	

Table A.8. 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 3.1 and Equation (1).	transactions, MTS & own calculations	n
Order splitting (dummy)	Equals one if a trade is part of a meta order and zero otherwise. A meta order is a series of at least two trades by the same dealer in the same bond and in the same direction with no offsetting trades and at most 2 trading days between two consecutive trades.	transactions & own calculations	d, b, i
Informedness	Log of the inverse time since a dealer last traded the same bond. Winsorized at the 1 and 99% percentile and standardized at the dealer level.	transactions & own calculations	d, b, i
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
Aggregate order flow	Imbalance of the aggregate order flow (buy minus sell volume, 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 at 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 (buy minus sell volume) over all Bunds on the same day prior to the trade, measured as a share of her average daily trading volume. The variable sign is set 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	Total trading volume of the dealer in our sample. Nominal amount in trillion EUR.	transactions	i
Trade size (log)	Logarithm of market value of trade, where market value is in EUR.	transactions	n

Table A.8 continued on next page.

Table A.8 continued from previous page.

Variable	Description	Source	Variation
Trade size $10-30$ million EUR (dummy)	Equals one if 10 million EUR $\leq$ nominal trade size $\leq$ 30 million EUR, and zero otherwise.	transactions	n
Trade size $>$ 30 million EUR (dummy)	Equals one if nominal trade size $>$ 30 million EUR, and zero otherwise.	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
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 (3) in Table 5, specification (1), cf. section 4.1.2.	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 (5) in Table 5, specification (2), cf. section 4.1.2.	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 (5) in Table 5, specification (2), cf. section 4.1.2.	own calculations	n

Table A.9. Statistics of Explanatory Variables: Descriptive statistics of explanatory and control variables as defined in Table A.8. The sample consists of interdealer trades for a minimum trade size of 2.5 million EUR for the following samples: 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
Order splitting (dummy)	0.35							2,179
Informedness	-1.34	3.69	-5.85	-4.01	-2.45	0.58	6.57	1,698
Price impact (15min)	1.53	6.28	-3.46	0.00	0.49	1.88	10.91	2,138
Aggregate order flow	-1.92	140.36	-209.22	-129.95	-13.33	130.81	211.62	2,179
Order book imbalance	-1.30	28.66	-32.75	-7.25	-0.00	10.00	25.55	2,179
Inventory	0.19	0.22	0.00	0.00	0.09	0.31	0.66	2,179
Volatility	1.73	2.51	0.10	0.28	0.74	2.12	7.13	2,176
Dealer Volume	0.30	0.30	0.00	0.01	0.11	0.65	0.67	2,179
Trade size 10-30 million EUR (dummy)	0.43							2,179
Trade size > 30 million EUR (dummy)	0.01							2,179
Round trade size (2.5/5/10 mn EUR, dummy)	0.83							2,179
Trade size (log)	15.78	0.53	14.80	15.45	15.79	16.14	16.46	2,179
Inv. Mills OTC	0.66	0.42	0.07	0.36	0.62	0.91	1.40	1,695
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
Cheapest-to-deliver (dummy)	0.04							2,179
2-years Schatz (dummy)	0.21							2,179
5-years Bobl (dummy)	0.22							2,179
30-years Bund (dummy)	0.12							2,179
Issuance day (dummy)	0.05							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

Table A.9 continued on next page.

Table A.9 continued from previous page.

Panel B: D2D via bilateral OTC

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Order splitting (dummy)	0.19							6,791
Informedness	-2.11	2.62	-5.58	-3.92	-2.56	-0.87	3.23	6,061
Price impact (15min)	0.27	3.86	-4.89	-0.87	0.00	1.24	5.91	6,582
Aggregate order flow	8.50	147.35	-221.18	-133.93	24.01	148.68	223.89	6,791
Order book imbalance	1.53	15.14	-20.00	-5.00	0.00	10.00	20.00	6,791
Inventory	0.21	0.23	0.00	0.01	0.13	0.34	0.69	6,791
Volatility	1.69	2.58	0.11	0.51	1.25	2.28	4.59	6,789
Dealer Volume	0.26	0.27	0.00	0.02	0.11	0.42	0.67	6,791
Trade size 10-30 million EUR (dummy)	0.28							6,791
Trade size $>$ 30 million EUR (dummy)	0.07							6,791
Round trade size (2.5/5/10 mn EUR, dummy)	0.26							6,791
Trade size (log)	15.90	0.89	14.85	15.22	15.60	16.37	17.74	6,791
Inv. Mills OTC	0.14	0.20	0.00	0.02	0.05	0.18	0.57	6,059
Inv. Mills bilateral	-0.87	0.35	-1.53	-1.07	-0.80	-0.62	-0.36	6,755
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
Cheapest-to-deliver (dummy)	0.07							6,791
2-years Schatz (dummy)	0.10							6,791
5-years Bobl (dummy)	0.24							6,791
30-years Bund (dummy)	0.05							6,791
Issuance day (dummy)	0.02							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

Table A.9 continued on next page.

Table A.9 continued from previous page.

Panel C: D2D via broker

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Order splitting (dummy)	0.33							13,282
Informedness	-1.02	2.90	-4.59	-3.02	-1.68	0.26	5.41	12,499
Price impact (15min)	0.11	5.00	-6.34	-0.98	0.00	1.31	6.84	12,963
Aggregate order flow	12.95	145.88	-198.54	-136.61	57.02	148.98	212.20	13,282
Order book imbalance	1.01	14.98	-20.00	-5.00	-0.00	10.00	20.00	13,282
Inventory	0.22	0.22	0.00	0.03	0.15	0.34	0.66	13,282
Volatility	2.09	8.04	0.13	0.53	1.41	2.54	6.35	13,269
Dealer Volume	0.32	0.24	0.03	0.09	0.22	0.65	0.67	13,282
Trade size 10-30 million EUR (dummy)	0.42							13,282
Trade size > 30 million EUR (dummy)	0.30							13,282
Round trade size (2.5/5/10 mn EUR, dummy)	0.13							13,282
Trade size (log)	16.73	1.02	14.96	15.91	16.95	17.57	18.35	13,282
Inv. Mills OTC	0.08	0.18	0.00	0.00	0.02	0.06	0.47	12,488
Inv. Mills broker	0.45	0.32	0.09	0.19	0.36	0.66	1.06	12,936
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
Cheapest-to-deliver (dummy)	0.16							13,282
2-years Schatz (dummy)	0.13							13,282
5-years Bobl (dummy)	0.22							13,282
30-years Bund (dummy)	0.11							13,282
Issuance day (dummy)	0.07							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

Table A.10. 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 F. Panel A extends Table 2 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 3. *OTC discount*, defined in Equation (1) in Section 3.1, 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.11. OTC Discount in the D2C segment. OLS estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ on dealer-to-customer trades (cf. Equation (10) and Appendix F). The dependent variable, *OTC discount*, defined in Equation (1) in Section 3.1, 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 (cf. Table A.10). 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)	-1.9248**	-1.9049**	-1.8894**	-1.5657***	-1.5615***	-1.5655***
	(-2.3499)	(-2.3301)	(-2.3130)	(-3.0778)	(-3.0536)	(-3.0601)
Order splitting (dummy)	-2.8023	-2.8602	-2.8876	-3.7825***	-3.8495***	-3.9523***
	(-1.3923)	(-1.4267)	(-1.4315)	(-3.1212)	(-3.1718)	(-3.2485)
Aggregate order flow	-1.8597**	-1.8441**	-1.8707**	-1.4506***	-1.4366***	-1.4527***
	(-2.5081)	(-2.4591)	(-2.5178)	(-3.0704)	(-3.0538)	(-3.1128)
Order book imbalance	-1.0607*	-1.0515*	-1.0623*	-0.7813*	-0.7822*	-0.7938*
	(-1.7031)	(-1.6836)	(-1.7035)	(-1.7851)	(-1.7785)	(-1.8102)
Volatility	-7.1139***	-7.0507***	-6.9431***	-7.3037***	-7.2631***	-7.2450***
	(-4.4650)	(-4.4256)	(-4.3991)	(-7.6129)	(-7.6622)	(-7.6741)
Trade size (log)	-3.4974***	-3.4973***	-3.5328***	-1.2716*	-1.2758*	-1.1816
	(-3.1888)	(-3.1863)	(-3.2148)	(-1.7678)	(-1.7852)	(-1.6536)
Dealer FE (D2D)		0.9547			1.7761**	
		(0.8171)			(2.3238)	
Overall trade volume (dealer)			3.3791***			2.9699***
			(2.8386)			(3.3673)
Intercept	50.5259***	50.5465***	50.5660***	54.6739***	54.6998***	54.7154***
	(79.5373)	(79.5164)	(80.1384)	(115.6390)	(115.9633)	(116.5411)
R^2	0.3170	0.3171	0.3184	0.2960	0.2965	0.2975
R^2_{adjusted}	0.2507	0.2506	0.2520	0.2534	0.2539	0.2549
R^2_{within}	0.0385	0.0387	0.0404	0.0354	0.0362	0.0375
N	5,491	5,491	5,491	11,920	11,920	11,920
Bond FE	yes	yes	yes	yes	yes	yes
Customer FE	yes	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes	yes

Recent Issues

No. 297	Dimitrios Kostopoulos, Steffen Meyer, Charline Uhr	Ambiguity and Investor Behavior
No. 296	Reint Gropp, Thomas Mosk, Steven Ongena, Ines Simac, Carlo Wix	Supranational Rules, National Discretion: Increasing Versus Inflating Regulatory Bank Capital?
No. 295	Besart Avdiu, Alfons J. Weichenrieder	Financing Costs and the Efficiency of Public-Private Partnerships
No. 294	Christian Alemán, Christopher Busch, Alexander Ludwig, Raül Santaeulàlia-Llopis	Evaluating the Effectiveness of Policies Against a Pandemic
No. 293	Christoph Hambel, Holger Kraft, André Meyer-Wehmann	When Should Retirees Tap Their Home Equity?
No. 292	Andrea Modena	Recapitalization, Bailout, and Long-run Welfare in a Dynamic Model of Banking
No. 291	Loriana Pelizzon, Satchit Sagade, Katia Vozian	Resiliency: Cross-Venue Dynamics with Hawkes Processes
No. 290	Nicola Fuchs-Schündeln, Dirk Krueger, Alexander Ludwig, Irina Popova	The Long-Term Distributional and Welfare Effects of Covid-19 School Closures
No. 289	Christian Schlag, Michael Semenischev, Julian Thimme	Predictability and the Cross-Section of Expected Returns: A Challenge for Asset Pricing Models
No. 288	Michele Costola, Michael Nofer, Oliver Hinz, Loriana Pelizzon	Machine Learning Sentiment Analysis, COVID-19 News and Stock Market Reactions
No. 287	Kevin Bauer, Nicolas Pfeuffer, Benjamin M. Abdel-Karim, Oliver Hinz, Michael Kosfeld	The Terminator of Social Welfare? The Economic Consequences of Algorithmic Discrimination
No. 286	Andreass Hackethal, Michael Kirchler, Christine Laudenbach, Michael Razen, Annika Weber	On the (Ir)Relevance of Monetary Incentives in Risk Preference Elicitation Experiments
No. 285	Elena Carletti, Tommaso Oliviero, Marco Pagano, Loriana Pelizzon, Marti G. Subrahmanyam	The COVID-19 Shock and Equity Shortfall: Firm-Level Evidence from Italy