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Abstract

We document a sizable OTC discount in the interdealer market for German sovereign bonds where exchange and over-the-counter trading coexist: the vast majority of OTC prices are favorable with respect to exchange quotes. This is a challenge for theories of OTC markets centered around search frictions but consistent with models of hybrid markets based on information frictions. We show empirically that proxies for both frictions determine variation in the discount, which is largely passed on to customers. Dealers trade on the exchange for immediacy and via brokers for opacity and anonymity, highlighting the complementary roles played by the different protocols.

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

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

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I. Introduction

Most fixed-income and derivative instruments trade in over-the-counter (OTC) markets. However, in some asset classes dealers can also trade with each other on electronic central limit order books (CLOB) provided by exchange platforms. The interdealer segment of the market for German federal government debt is a case in point, thus providing a unique laboratory to study dealer pricing and trading decisions in a segmented market structure.[1] Understanding the functioning of the interdealer market is important as it plays a crucial role in helping dealers to provide liquidity to their clients.[2]

German sovereign bonds, generally known as *Bunds*, enjoy benchmark status for Europe as safe assets and the Bund market is considered one of the most liquid sovereign bond markets in the world. In this paper, we combine a unique regulatory dataset that comprises *all* trades involving at least one financial institution regulated in Germany between 2011 and 2017 with the full limit order book of the leading interdealer exchange MTS, in order to study dealers' pricing and venue choice decisions in interdealer (D2D) Bund transactions and to analyze their effect on trading conditions in the dealer-to-customer (D2C) market segment.

We make several contributions. First, we show that while dealer banks actively trade via the exchange, most interdealer transactions in the Bund cash market are executed over-the-counter, either bilaterally or via interdealer brokers. We document that the vast majority of these OTC trades have lower transaction costs than exchange quotes, thus giving rise to a pervasive *OTC discount*. This is surprising in light of theories of OTC markets centered around search frictions, but is consistent with theories of hybrid markets based on information frictions. Second, we show that in addition to information frictions, search and other market frictions explain variation in the OTC discount. Third, we document the presence of an OTC discount also in the dealer-to-customer segment and relate it to the market structure of the D2D segment. Finally, we highlight the importance

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[1] Securities with a similar market structure are the US Treasury bond market (see, e.g., Barclay, Hendershott, and Kotz, 2006), several other European sovereign bonds (Holland, 2001), foreign exchange, and the index CDS market (Riggs, Onur, Reiffen, and Zhu, 2019; Collin-Dufresne, Junge, and Trolle, 2020). Edwards, Harris, and Piwowar (2007) report that also 5% of U.S. corporate bonds are listed on NYSE.

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

of interdealer brokers that so far have been largely unexplored in the literature. As a side contribution we provide a detailed description of the Bund market microstructure.[3]

Our empirical setup has a crucial advantage relative to previous studies addressing similar questions. In the D2D Bund market dealers are active in both the exchange and OTC segments *simultaneously*. Hence, for any OTC trade we can define the contemporaneous conditions of trading on the exchange. This allows us to precisely measure differences in transaction costs and relate them to trade, dealer and bond characteristics. Moreover, since we also observe customer trades, we can analyze how trading conditions in the D2D market feed through to the D2C segment. While several previous studies have analyzed venue choice for equity markets, thus far there is little evidence for bond markets.[4] Two notable exceptions are Barclay, Hendershott, and Kotz (2006), who study the choice between electronic and voice brokerage for U.S. Treasuries that go off-the-run, and Hendershott and Madhavan (2015), who analyze U.S. corporate bonds trading both OTC and on a request-for-quote (RFQ) platform. In contrast to these studies, our dataset allows us to directly compare transactions costs for exchange and OTC trading in a setting consistent with theories of hybrid markets (Seppi, 1990; Grossman, 1992; Lee and Wang, 2017).

The simultaneity of observed exchange and OTC trading allows us to compute our main quantity of interest, OTC discount, which measures the transaction cost advantage of an OTC trade with respect to potential execution of the same trade on the exchange at the same time. A positive OTC discount corresponds to cheaper execution in the OTC segment.[5] Our main finding is that the vast majority of transactions in the D2D segment trades at a lower price than the one attainable on MTS. Specifically, more than 80 percent of interdealer OTC trades take place at a discount relative to the price at

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[3] Upper and Werner (2002) analyze the information content of the Bund futures and cash market. Schlepper, Hofer, Riordan, and Schrimpf (2020) study the effect of central bank purchases on Bund yields, without however providing a detailed description of the Bund cash market.

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

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

which the same security would have traded on the exchange at the same time. On average, the OTC transaction cost for trades between dealers is about 35 percent lower than the corresponding cost on MTS.

This finding is surprising in light of a previous literature arguing that a shift towards exchange trading with pre-trade transparency and an all-to-all structure would significantly improve bond market efficiency (e.g. Harris, Kyle, and Sirri, 2015). For example, Edwards, Harris, and Piwowar (2007) and Biais and Green (2019) provide evidence suggesting that transaction costs are higher in OTC than in exchange markets. These results are in line with theories of pure OTC markets in which *market frictions* drive transactions costs (e.g., Stoll, 1978; Duffie, Gârleanu, and Pedersen, 2005). These frictions include search costs, bargaining power, and inventory management considerations which are less relevant in exchange markets. If these were the dominating frictions, an exchange should be the most efficient market for a frequently traded asset such as the Bund.

Yet, we do observe that the majority of trades is executed OTC, which suggests that other frictions may also play an important role. Specifically, the OTC discount we document is consistent with theoretical models that emphasize *information frictions* as the main difference between trading mechanisms in hybrid markets (e.g., Seppi, 1990; Lee and Wang, 2017).[6] We know from the seminal works of Kyle (1985) and Glosten and Milgrom (1985) that information frictions such as adverse selection determine liquidity conditions on exchanges. These information frictions are typically associated with private information about the fundamental value of the asset, which arguably should play only a minor role in the case of a safe asset such as the Bund (Gorton, 2017). However, even in the absence of private information about fundamental asset values, information frictions related to order flow can be important (Burdett and O'Hara, 1987; Colliard and Demange, 2020).

Dealers thus face a trade-off between the exchange venue, which alleviates market frictions, and the OTC venue which may mitigate information frictions. To assess the relative importance of both channels as drivers of OTC discount we consider a host of

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[6] It is also in line with costly immediacy of market orders on an exchange (Zhu, 2014; Menkveld, Yueshen, and Zhu, 2017).

proxy variables for market and information frictions. We find that both are quantitatively important. More informed bilateral OTC trades receive significantly lower discounts. At the same time, traders with more bargaining power receive higher discounts.

These results account for the potential endogeneity arising from the joint determination of venue choice and pricing decisions. We study dealers' venue choice among trading on the exchange, bilaterally or via brokers as a sequential decision. We first estimate a probit model relating the probability that a dealer will perform a given trade on the exchange rather than over-the-counter to dealer and trade characteristics. Second, for OTC trades we estimate a probit model for whether a dealer will route a given trade via a broker instead of negotiating bilaterally. We find that trade size is the main driver of these decisions, giving rise to a "pecking order" where trading activity shifts from the exchange to bilateral negotiations to broker facilitation as the traded amount increases. Moreover, trading on the exchange is more likely (i) when trades are informed, i.e. for trades that are part of a larger order that has been split, (ii) on days with high intraday volatility, and (iii) for less liquid assets, i.e. Bunds with long maturities and Bunds not closely linked to a futures contract.

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. This confirms that relating the transaction costs in the OTC segment to those on the exchange is appropriate.

A unique feature of our data is that we can distinguish between bilateral OTC trades and those routed via interdealer brokers. Brokers provide opacity, as they do not disseminate post-trade information, and anonymity, since dealers are unaware of the identity of their counterparty. Surprisingly, we find that more than 75 percent of Bund interdealer volume is broker-intermediated. Using a matched sample of otherwise similar bilateral and broker-facilitated transactions, we document that the latter feature significantly higher transaction costs than bilaterally negotiated OTC trades, while still being favorable with respect to the exchange. Taking into account trade, bond, and dealer characteristics, broker-intermediated trades receive a 30% lower OTC discount than bilateral trades. Finally, we measure price impact as the average reaction of mid-prices on the exchange to trades in either protocol, and show that broker trades have essentially no price impact, while bilateral and especially exchange trades do. This suggests that brokers allow dealers to trade with each other while at the same time concealing their order flow and protecting them against price revision risk (Naik, Neuberger, and Viswanathan, 1999) or front-running (Harris, 1997; Brunnermeier and Pedersen, 2005). Consistent with this interpretation, we see that particularly large, and thus central, dealers prefer to trade with each other via brokers instead of bilaterally. These results are in line with Hagströmer and Menkveld (2019) who show that strongly connected central FX dealers are more informed, and with Anderson and Liu (2019) who find that the usage of interdealer brokers by dealers in the U.S. Treasury market increases with interest rate risk. However, our findings contrast with those in Barbon, Di Maggio, Franzoni, and Landier (2019) and Di Maggio, Franzoni, Kermani, and Sommavilla (2019) who document that equity brokers leak private information from informative trades to their institutional clients.

What is the economic relevance of the OTC discount we document? Remarkably, we find that D2C trades feature a similarly large OTC discount as interdealer trades. Moreover, market and information frictions play a quantitatively similar role as for OTC discount in the D2D segment. We show that dealers' bargaining position in the D2D market and the strength of the dealer-customer relationship are important drivers for the pass-through of OTC discount to clients. Therefore, the microstructure of the interdealer segment is key for understanding trading conditions in the overall market.

II. The Bund Market

A. Market Structure

German sovereign debt securities enjoy benchmark status in the Euro area and worldwide as a liquid and safe asset. They 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*).[7] In this study we focus on bonds with longer maturities, i.e. 2-year Schaetze, 5-year Bobls and 10- and 30-year Bunds, and, where not explicitly mentioning maturities, we hereafter refer to them jointly as Bunds.

German government securities are issued regularly by the German finance agency ("Deutsche Finanzagentur", *DFA*) either as new issues or as reopenings of already issued bonds.[8] On-the-run effects, which exist, e.g., for U.S. Treasury bonds, are much less pronounced in the Bund market, so we include both on-the-run and off-the-run Bunds in our analysis. Participants in this primary market are the members of the *Bund Issues Auction Group* which currently includes 36 international banks that commit to subscribing to a certain minimal amount of the total annual issuance.[9]

Secondary market trading occurs among dealers and between dealers and customers. We refer to these as the dealer-to-dealer (D2D) segment and the dealer-to-customer (D2C) segment of the market, respectively. The D2D segment features three distinct trading protocols: bilateral, via a broker, or on the interdealer exchange MTS.

In the bilateral protocol, dealers trade directly with each other in over-the-counter negotiations. These bilateral trades are generally only observed by the two dealers

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[7] 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).

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

[9] 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. 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/`.

involved, and not by other market participants. Dealers can also trade with each other via interdealer brokers. In this case, the initiating dealer communicates the trade request to a broker, who then undertakes to find a suitable counterparty and earns a fee. Crucially, the broker acts as a matched principal who is not taking any inventory, and the dealers involved are unaware of the identity of the counterparty.[10] As with bilateral D2D trades, broker trades are also unobserved by other market participants, i.e. there is no post-trade transparency.[11]

The third option for dealers to trade with each other is via an exchange. The only platform with a significant market share is the interdealer exchange MTS, which is operated as a fully electronic limit order book market.[12] During the hours from 8 a.m. to 5:30 p.m. CET dealers actively quote executable limit orders on MTS, and the depth on both the bid and ask side of the book is typically in excess of 100 million EUR for most bonds, while the minimum trade size is 2.5 million EUR. Unlike bilateral and broker-facilitated OTC trades, all trading activity on the exchange is observed by all market participants, implying that there is both pre- and post-trade transparency. In what follows, we refer to bilateral and broker trades jointly as *OTC trades*, in contrast to exchange trades on MTS.

Subscription services such as Bloomberg allow access to MTS prices and volumes at the best bid and ask levels in real time, also for non-MTS dealers. This, in conjunction with the availability of MTS data to researchers, has given MTS a benchmark function for European sovereign bond markets.[13] Regardless of trading protocol, cash trades are settled via repositories, so that there is essentially no counterparty risk. This segmented structure is not unique to the interdealer Bund market, and is very similar to that of

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

[11] 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.

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

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

other sovereign bond markets such as the UK Gilt market (Holland, 2001). In the U.S. Treasury market (Fleming, 1997; Fleming and Remolona, 1999; Mizrach and Neely, 2009) the order book of the BrokerTec platform assumes a role similar to that of MTS in the Euro area. On the BrokerTec platform size-discovery protocols such as the "work up" described in Duffie and Zhu (2017) and Fleming and Nguyen (2018) are heavily used. On MTS, similar protocols exist but play a negligible role.[14]

The dealer-to-customer (D2C) segment of the Bund market is dominated by bilateral OTC interactions between dealers and customers. Electronic platforms with a non-negligible market share are either mostly used as a pre-arranged trade facility or follow request-for-quote protocols. The Bund D2C segment is thus similar to the U.S. corporate bond market (O'Hara and Zhou, 2020) and other typical OTC markets.

B. Data Sources

Our study is based on a unique regulatory dataset of *all* Bund trades involving at least one German financial institution. Importantly, this trade repository includes bilateral D2C trades between German dealers and their customers as well as D2D trades from all three market segments. We link these data to the full limit order book data from the interdealer exchange MTS, giving us an almost complete view of all Bund trading. We study the sample period from June 1, 2011 through December 31, 2017.

The regulatory transactions data is based on reporting requirements of German financial institutions to the German Federal Financial Supervisory Authority (Bundesanstalt für Finanzdienstleistungsaufsicht, popularly known as "BaFin") and mandated by the German Securities Trading Act ("Wertpapierhandelsgesetz") and the respective regulation ("Wertpapierhandel-Meldeverordnung"). We refer to this dataset as *transactions data*. It includes any transaction by the reporting institutions in a wide set of securities, including German government bonds, and contains information on the price, size and time of the

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[14] 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 rarely used or executed. Further differences between the MTS and BrokerTec platforms are a) the number of bonds traded (in BrokerTec 6 on-the-run U.S. Treasury bonds are traded compared to about 60 Bunds on MTS), and b) the set of participants (36 dealer banks on MTS compared to around 100 participants on BrokerTec, including dealers, hedge funds and high-frequency trading firms).

trade, a flag indicating whether a trade was over-the-counter or the platform in which the trade was executed as well as an indicator whether a trade was a buy or a sell from the point of view of the reporting institution. Further, we have anonymous identifiers for the reporting agent and the counterparty of a trade, where the identifier for the counterparty can be missing if the counterparty has no reporting requirement to the German Federal Financial Supervision.[15]

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.[16] Bond characteristics are obtained from Bloomberg and Thomson Reuters Eikon as well as auction results published by the German finance agency.

C. Trading Activity

Table I describes the trading activity covered by our sample and the subsamples relevant for our analysis in terms of number of trades, aggregate trading activity, statistics of trade size, and market share by type of trading venue.

[**Table I about here.**]

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 DFA among Bund Issues Auction Group members pegs daily trading volume in the secondary (*cash*) market at more than 17 billion

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

[16] 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.

EUR. Our sample captures about 11% of this trading activity.[17] The trading activity not captured by our sample involves counterparties who both do not report to BaFin.

To categorize trades and to compute our variables of interest we require further knowledge on the initiator and counterparty. This information may be unavailable, either when a counterparty is not identified in the transactions data, or where we cannot identify the trade sign, e.g. for trades at exactly the MTS mid-price or outside of MTS trading hours.[18]

For about 210,000 of these trades (corresponding to a volume of roughly 1.5 trillion EUR) we are able to identify both the initiator and counterparty (labeled "init. & counterp. ID known" in Table I). We classify the involved parties as either dealers or customers based on their access to the interdealer exchange MTS. That is, we consider as dealers only those dealer banks that are active on the interdealer exchange, thus excluding, e.g., some primary dealers that forego MTS membership or dealers that are MTS members but never trade on the platform. According to this classification we observe about 47,500 interdealer trades between MTS dealers (labeled "D2D") and 123,000 dealer-to-customer trades between MTS dealers and their clients (labeled "D2C").[19]

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) with a total volume of 470 billion EUR represent more than 95% of overall interdealer trading volume. About 2,200 interdealer trades take place on the exchange 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") that account for 18.4% of overall

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[17] The survey, available at `https://www.deutsche-finanzagentur.de/en/institutional-investors/secondary-market/`, also includes trading activity in Bubills and inflation-linked bonds. For consistency we compute our sample coverage including trades in these securities in our transactions data.

[18] Quoting and trading activity on MTS is low during the first hour from 8:00 to 9:00 a.m. Therefore, we consider only trades from 9:00 a.m.

[19] The remainder consists of "C2C" trades between two non-MTS dealers. In defining as dealers only those institutions with access to the MTS platform we have taken a conservative approach that ensures that all dealers in our setting do have access to the MTS platform.

interdealer volume in our sample. The by far largest share of interdealer trading is done via brokers ("D2D via broker (D2B)"), both in terms of number of trades (about 13,300) and overall volume (77.9%). 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. A comparison of the cross-sectional distributions of trade size shows that these differences are primarily due to a higher share of very large trades via brokers.

Turning to the D2C segment, the average trade size 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 I. Comparing the cross-sectional distributions of the latter two subsamples suggests that there are only minor differences in terms of trade size. The D2C segment of the Bund market is dominated by bilateral OTC interactions between dealers and customers, which account for more than 90% of D2C volume throughout our sample period. Electronic platforms with a non-negligible market share are either mostly used as a pre-arranged trade facility or follow request-for-quote protocols.

III. Measuring Relative Transaction Costs

In this section, we measure the transaction cost of OTC trades relative to those on the exchange protocol of the interdealer Bund market. We start by defining *OTC discount* as the discount of OTC trades with respect to quotes on MTS. We show that the majority of D2D trades are cheaper when carried out over-the-counter. We then provide a number of theoretical arguments why this might be the case, before showing that customers receive a similar OTC discount in D2C trades. We study the drivers of protocol choice and relative transaction costs in Section IV.

A. Measuring OTC Discount

The absence of firm quotes in most bond markets implies that simple transaction cost measures that are commonly employed in equity markets, such as, e.g., the quoted spread, cannot be applied (Bessembinder, Spatt, and Venkataraman, 2020). A common alternative approach to estimating transaction costs in OTC markets is via proxies estimated over multiple trades such as, e.g., the imputed round-trip cost, price dispersion or effective bid-ask spread measures (Schestag, Schuster, and Uhrig-Homburg, 2016), whereas in hybrid RFQ settings it is common to compare prices to a benchmark price (Hendershott and Madhavan, 2015; O'Hara and Zhou, 2020).

Thanks to the presence and availability of limit order book data in our hybrid setting with an exchange, we can calculate an effective spread of OTC trades as the signed difference between the trade price and the quoted mid-price on the exchange:

$$\textit{effective spread}^{\text{OTC}} = 2\epsilon \left(\textit{price}^{\text{observed, OTC}} - \textit{price}^{\text{mid,MTS}} \right) \quad , \tag{1}$$

where $\textit{price}^{\text{observed, OTC}}$ is the price of an over-the-counter trade observed in our transaction data and $\textit{price}^{\text{mid,MTS}}$ is the contemporaneous MTS mid-price at the time of the trade. The trade sign ϵ is $+1$ (-1) for buyer- (seller-) initiated trades.[20]

However, we are not interested in the effective spread per se', but rather in the difference between transaction costs across interdealer trading protocols. Hence, our quantity of interest is the premium or the discount that OTC trades pay or receive with respect to bid and ask quotes on the exchange MTS. We define the *OTC discount* that a trader receives when initiating a trade as the difference in price between the virtual price

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[20] Since the transactions data does not include information on who initiated the trade, we infer the initiator of each trade by comparing the trade price to the contemporaneous mid-price on the exchange as e.g. in 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).

a trade would have incurred on the exchange and the observed price of an OTC trade, normalized by the respective virtual transaction cost on the exchange. Formally, OTC discount is defined as:

$$
\begin{aligned}
OTC\ discount &= \frac{\epsilon\left(price^{\text{virtual,MTS}} - price^{\text{observed, OTC}}\right)}{\left\|price^{\text{virtual,MTS}} - price^{\text{mid,MTS}}\right\|} \\
&= \frac{price^{\text{virtual,MTS}} - price^{\text{observed, OTC}}}{price^{\text{virtual,MTS}} - price^{\text{mid,MTS}}} \quad , \qquad (2)
\end{aligned}
$$

where $price^{\text{virtual,MTS}}$ is a virtual reference price which the same trade would have incurred on MTS at the same time. The denominator in Equation (2) is equal to the quoted half-spread on MTS. Hence, by our trade sign identification OTC discount is bounded from above by 100%.

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, whereas buys at the MTS ask price and sells at the MTS bid price have 0% OTC discount, i.e. 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. $price^{\text{virtual,MTS}}$ is the best ask (bid) price for buyer- (seller-) initiated trades. Hence, we disregard that larger trades would have to execute also against quotes at deeper levels of the limit order book ("walking up the book"). We do so 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. Notwithstanding the smaller market share of MTS compared to OTC, all limit orders on MTS are executable and available volume at both levels of the book is typically on the order of 100 million EUR, larger than the 95th percentile of OTC interdealer trade size. MTS bid- and ask quotes are thus a perfectly suitable reference price. Second, in choosing the quoted price at the best as $price^{\text{virtual,MTS}}$ our measurement for OTC discount is conservative (i.e. smaller) with respect to a virtual price that takes into account the depth of the order book. Third, this measure is independent of trade size and allows for comparisons across size.

Consequently OTC discount can also be expressed as the difference between the quoted bid-ask spread on the exchange and the effective spread as a fraction of the quoted spread:

$$OTC\ discount = \frac{quoted\ spread - effective\ spread^{\text{OTC}}}{quoted\ spread} \quad , \tag{3}$$

where *quoted spread* is the contemparenous quoted bid-ask spread on MTS, i.e. $price^{\text{ask,MTS}} - price^{\text{bid,MTS}}$.

[Table II about here.]

Table II shows the descriptive statistics of OTC discount for the same subsamples of OTC trades as those discussed above.[21] Both mean and median of OTC discount are positive across all considered subsamples, and we reject the null hypothesis that the average OTC discount is zero at the 0.01% significance level using a simple t-test.

For interdealer trades with a size of at least 2.5 million EUR the average OTC discount equals 34.7%. This implies that dealers pay on average just about two thirds of the quoted MTS bid-ask spread when trading among each other over-the-counter. The median OTC discount is even larger at 61.6% and the trade at the 95th percentile receives a discount of 96%, implying a trade price just above (below) the MTS mid for buys (sells). Less than 16% of trades incur an OTC premium.

These numbers mask sizable differences in the distribution of the OTC discount between bilateral and broker OTC trades, however. Bilateral OTC trades receive a considerably larger average discount of 54.6% as opposed to 24.6% for brokered trades. Bilateral trades

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[21] We winsorize OTC discount for each subsample at the 0.5th and 99.5th percentile.

also have a lower share of trades with an OTC premium: 6.9% as opposed to 20.4% for trades via brokers.[22]

Figure 2 shows the histogram of OTC discount for interdealer trades with a minimum size of at least 2.5 million EUR, where Panel (a) refers to bilaterally negotiated trades and Panel (b) is based on transactions via brokers. Both subsets feature a distribution that is heavily tilted towards positive values of OTC discount. Hence, in the majority of cases, trading over-the-counter is cheaper than on the exchange. While the distribution for bilateral trades is more right-skewed, broker trades have a wider distribution and feature OTC premia or trades exactly at the MTS best more often.

[Figure 2 about here.]

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

In the Appendix, we show that these results are robust to our definition of OTC discount. First, we explicitly account for the effects of large trades walking up the book, i.e. $price^{\text{virtual,MTS}}$ is no longer the price at the best, but the actual price that would result for a trade of a given size given the current state of the limit order book. 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 (2) becomes $price^{\text{mid,MTS}}$. Both alternative definitions equally give rise to pervasive and economically large OTC discount.

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[22] The larger share of OTC premia for broker trades is related to their typically larger size. In the Appendix we show that, when including the effects of trades walking up the book, the share of trades with an OTC premium is 5.4% and 13.2% for bilateral and broker-facilitated OTC trades respectively.

B. Why is OTC Trading Cheaper?

It is a widely held view that pure exchange markets feature lower transaction costs than pure OTC markets (cf. Edwards, Harris, and Piwowar, 2007; Harris, Kyle, and Sirri, 2015; Abudy and Wohl, 2018; Bessembinder, Spatt, and Venkataraman, 2020). Biais and Green (2019), for example, document that transaction costs for corporate and municipal bonds were lower in the early 20th century, when they were traded on exchange in a limit order book, than in their current OTC structure.

On the surface, our finding that OTC transaction costs for Bunds are lower than on the exchange may therefore appear surprising. That said, our setting is different from those studied in the papers cited above, because it compares OTC and exchange protocols *co-existing* in a hybrid market. Theories of such hybrid markets focus on information frictions and predict lower transaction costs for OTC trades than in the exchange protocol. For example, in Seppi (1990) a dealer's knowledge of the identity of the counterparty enables her to enter an implicit commitment against "bagging the street", i.e. for the counterparty not to trade the same asset too soon afterwards. This allows for lower transaction costs for OTC trades compared to the exchange, reflecting the reduced front-running or price revision risk on the part of the dealer. In the model of Lee and Wang (2017) liquidity providers price discriminate in OTC transactions by favoring uninformed investors, whereas on the exchange they set wider quotes in order to avoid being adversely selected. Importantly, information need not necessarily be about fundamental value, but can reflect order flow as in Grossman (1992). In his model, dealers' knowledge of "unexpressed order flow" allows them to provide better trading conditions over-the-counter than on the exchange. For safe and highly liquid assets such as Bunds, this is likely to be the relevant information that dealers have access to.

In addition to such concerns relating to information frictions, trading on the exchange is typically more immediate than the search process associated with OTC trading. A higher transaction cost on the exchange may thus reflect the cost of immediacy and the search cost that a trader avoids by routing to the exchange and bypassing the OTC segment.

There are only few empirical studies that look at hybrid market settings with similarities to the one analyzed here. A recent exception is Holden, Lu, Lugovskyy, and Puzzello (2020) who study the introduction of OTC trading to a previously pure exchange market. Consistent with our findings, they observe that in the new setting average transaction costs for large trades are higher on the exchange than OTC and that most trades take place in the OTC segment. In the interdealer market for index CDS studied by Collin-Dufresne, Junge, and Trolle (2020), dealers cannot only trade in a limit order book, but also using a mid-market matching or a workup protocol. They find that transaction costs (and price impacts) are lower for the latter two protocols than for the limit order book, in a setup quite similar to equity markets with dark pools as studied in Menkveld, Yueshen, and Zhu (2017) and modeled in Zhu (2014). Our study is different in that we compare the pricing of OTC trades to an exchange with a limit order book and thus have a setting that is more closely aligned with the theoretical studies of hybrid markets such as Seppi (1990); Grossman (1992); Lee and Wang (2017).

In sum, there are several theoretical reasons why OTC trading might be cheaper in a hybrid market setting as the one for Bunds. That said, certain aspects of the Bund market microstructure are not captured by existing theories. For example, to the best of our knowledge there is no theory involving the co-existence of a pure bilateral and a broker-intermediated OTC segment. We observe that the vast majority of interdealer OTC trades is transacted via brokers, despite the fact that broker-intermediated trades receive a substantially lower OTC discount. It is also worth pointing out that a pervasive OTC discount and a small market share of the exchange may be two sides of the same coin. If prices on the exchange were more favorable, thus implying a smaller OTC discount, the exchange would likely attract a higher market share.

To guide future theoretical work, in the remainder of the paper we quantitatively study the determinants of protocol choice and of OTC discount. In our empirical analysis, we attempt to capture as precisely as possible the various frictions that the theoretical literature on OTC and hybrid market has pointed to. We discuss these frictions and our measurement in Section IV.

C. Dealer-to-Customer (D2C) Trades

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 Table II, is 49.8%, only slightly less than for bilateral D2D transactions. For comparability with the interdealer sample we restrict the D2C sample to exclude clients trades below 2.5 million EUR, i.e. the minimal trade size on MTS. 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%. Only 12.1% of trades incur an OTC premium. These summary statistics suggest that dealers pass on a substantial share of their trading advantage to their clients. We empirically quantify the pass-through of the OTC discount from the D2D to the D2C segment in Section IV.E. 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 (2020) for U.S. corporate bonds and Hau, Hoffmann, Langfield, and Timmer (2019) for foreign exchange derivatives. These results are consistent with Vogel (2019) who develops a 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.

IV. Protocol Choice and Drivers of OTC Discount

Theories of OTC and hybrid markets link transaction costs to frictions related to market or information structure. Market frictions refer to specific market characteristics that lead to price dispersion, e.g. search costs, bargaining power and dealer inventory. Information frictions imply that the pricing of a trade depends on differences in the involved counterparties' information sets. In this section, we empirically assess to what extent these frictions affect the choice of trading protocol and relative trading costs. We start by discussing our regression setup. We then present our measurement of the various relevant frictions. Finally, we document and discuss our empirical results for the drivers of venue choice, OTC discount in the D2D segment, and on the pass-through to the D2C segment.

A. Regression Specification

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

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

If a trade is not executed on the exchange, we next study the decision to trade bilaterally or via a broker.

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

$$Pr(OTC_n|\omega_{I,n}) = \Phi(\gamma_I' \omega_{I,n}) \tag{4}$$

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

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

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

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

$$OTC\ discount_n = \beta_v' v_n + \beta_{\text{OTC}} \hat{\lambda}_n^{\text{OTC}} + \beta_s \hat{\lambda}_n^s + \varepsilon_n, \tag{6}$$

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

B. Frictions in OTC and Hybrid Markets

In this section, we motivate our choice of regressors to capture the potential drivers of venue choice and OTC discount. We first discuss their expected impact on OTC transaction costs. Then, we compare these to the exchange and highlight expected implications for protocol choice. To the extent possible, we derive these predictions from the prior literature on market and information frictions. Detailed definitions of all proxy variables as well as control variables are provided in Table A.1, in the Appendix, and their descriptive statistics in Table A.2. Variable definitions generally take the point of view of the trader initiating the transaction, i.e. requesting liquidity from other dealers.

Market frictions. Search-based models of over-the-counter markets identify bargaining power as the crucial driver of OTC transaction costs. They predict that dealers with more bargaining power face lower transaction costs (Duffie, Gârleanu, and Pedersen, 2005, 2007; Duffie, 2012). Because dealers cannot exercise bargaining power on the (anonymous) exchange, this implies that dealers with greater bargaining power should receive larger OTC discounts when they initiate a trade.

Duffie, Gârleanu, and Pedersen (2005) argue that access to outside options increases dealers' bargaining power. In the Bund market, dealers can trade OTC or on the exchange. Since large trades become increasingly expensive on MTS, this outside option diminishes with increasing trade size. Therefore the OTC discount should decrease as trade size increases. We capture this relation with the variable *Trade Size*, measured in logarithmic scale. Note that this is in contrast to pure OTC markets, where transaction costs typically decrease with increasing trade size (see Edwards, Harris, and Piwowar, 2007).

Dealers' inventory is a key factor in trading and pricing decisions. Dealers providing liquidity adapt their bid and ask quotes in order to balance inventory positions (see, e.g., Stoll, 1978; Amihud and Mendelson, 1980; Ho and Stoll, 1981, 1983). Inventory requires balance sheet capacity, which may constrain the dealers' trading activity (see, e.g., Gromb and Vayanos, 2002; Bessembinder, Jacobsen, Maxwell, and Venkataraman, 2018; Dick-Nielsen and Rossi, 2019; Friewald and Nagler, 2019). Dealers with large inventory are more likely to be constrained, and hence in a worse bargaining position. We use the variable *Inventory* to capture a dealer's inventory just before a trade. It is calculated from the transactions data as the absolute value of the net imbalance of the dealer from all trades in Bunds on the same day prior to the trade, and normalized by the dealer's average daily trading volume. For a trade reducing a dealer's inventory position the variable is negative, and for such a trade we expect a lower OTC discount.

Search costs amplify inventory risk on volatile days. This limits a dealer's outside option to trade and reduces her bargaining power. The dummy variable *Volatility* takes the value of one if the intraday price volatility of a bond is above the 90th percentile across all bonds and days in our sample, and zero otherwise. We expect a lower OTC discount for these more volatile days.

Previous studies have identified the dealer network structure and trading relations as important factors for pricing in OTC markets, e.g. for corporate bonds (Di Maggio, Kermani, and Song, 2017; Hendershott, Li, Livdan, and Schürhoff, 2020), securitized assets (Hollifield, Neklyudov, and Spatt, 2017), and municipal bonds (Li and Schürhoff, 2019), in line with theoretical studies such as Glode and Opp (2020). First, more central dealers benefit from their position and are able to charge higher markups. Second, markups are lower in established trading relationships, and especially so in times of turmoil (see also Glode and Opp, 2016). Unfortunately, since we observe only trades involving German financial institutions, we are unable to reconstruct the full network structure of interdealer trades. Thus, we refrain from using network measures in our analysis. Instead, we rely on trading volume as an indirect measure of network centrality (cf. Nikolova, Wang, and Wu, 2020). We use the total trading volume of a dealer throughout the sample (*Dealer Volume*) to distinguish between large and small dealers. As an alternative, we use dealer-fixed effects to capture differences in centrality and individual bargaining power. Dealers with larger trading volume are associated with greater centrality and higher bargaining power. We expect larger (smaller) dealers to receive a higher (lower) OTC discount in trades they initiate.

Information frictions. Information-based theories of hybrid markets typically distinguish between uninformed (liquidity-motivated) traders and informed traders (see, e.g., Seppi, 1990; Lee and Wang, 2017). In the model of Lee and Wang (2017), liquidity providers (imperfectly) infer the information set of their counterparties via their "reputation" in OTC interactions, but not on the anonymous exchange. Accordingly, dealers adjust their price reaction (e.g. in setting quotes and limit orders) to the perceived informedness of trades. In this spirit, we identify trades with larger price impact as being more informed. Empirically we capture price impact by using the price change 15 minutes after each trade, *Price impact (15min)*) (following Collin-Dufresne, Junge, and Trolle (2020)). We expect a lower OTC discount for more informed trades, i.e. those with a higher price impact.

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

Order flow is another important driver of transaction costs. Czech, Huang, Lou, and Wang (2020) show that the order flow by hedge funds and mutual funds predicts bond returns in the UK Gilt market, and Ranaldo and Somogyi (2020) present similar findings for the FX market. These results are consistent for example with Grossman (1992) where information need not necessarily be about fundamental value but can also refer to expressed and unexpressed order flow. Consistently, in the model of Babus and Kondor (2018) central dealers are better informed through the order flow they receive, trade at lower costs and earn higher profits. In our setup we associate trading in the same direction as the market with a higher degree of informedness, and therefore expect a lower OTC discount for such trades.[23] We use two proxy variables that capture the net order flow of the market, one based on OTC transactions and the other based on the imbalance

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[23] Other models associate order flow with bargaining frictions. The model of Colliard, Foucault, and Hoffmann (2018) features a core-periphery structure where dealers' bargaining power and price dispersion depend on the aggregate positions in the core and periphery of the market, among other factors. Transaction costs would also decrease with order flow under this alternative interpretation.

of the limit order book. *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. It is positive when trading in the same direction as the market. *Order Book Imbalance* captures the contemporaneous imbalance between the best three levels on both sides of the limit order book of the same Bund and is also defined as positive when trading in the market direction that is implied by the order book imbalance. For both variables we expect a negative relation with OTC discount.

Let us stress that while these frictions are present in all protocols, their impact on transaction costs likely differs substantially. Bid and ask prices on the exchange, which we take as our reference, are not influenced by the individual dealers' positions. For example a dealer with a large inventory can always trade on the exchange (albeit at a higher price), whereas the OTC search process exposes her to price revision risk. Hence she is incentivized to trade at a lower discount to wind down the position.

Implications for protocol choice. Transaction cost is likely one of the key drivers behind dealers' trading decisions. Consequently, the same set of market and information frictions that affect trading costs should also influence the choice of trading protocol. More precisely, when a dealer decides between trading on the exchange or OTC, the frictions that increase the OTC discount will also raise the marginal propensity of the dealer to trade over-the-counter. We therefore rely on a similar set of variables to model the venue choice in the first-stage probit regressions. We expect market frictions that lead to smaller bargaining power to increase the likelihood that a trade takes place on the exchange. Similarly, more informed trades should be more likely to take place on the exchange.

That said, other factors may also play a role. For example, dealers may sometimes require opacity and therefore prefer to route transactions via a broker that would otherwise have been executed on the exchange. There is scarce theoretical literature explicitly modeling the role of brokers in OTC markets. A notable exception is Bruche and Kuong (2019) who study a model in which dealers need to raise external financing in order to intermediate trades. Since the amount dealers can raise is limited, the model predicts that the share of brokered trades should be higher for larger trades.

C. Protocol Choice in the Interdealer Segment

In this section, we study the determinants of dealers' decision to execute a given trade in either segment of the bilateral OTC market or on the exchange. We start by modeling dealers' choice to trade on the exchange or over-the-counter. Given a trade is conducted OTC, we then model the decision to route it via a broker or execute it directly with another dealer. Both decisions are modeled via probit regressions.

Exchange versus OTC To study dealers' decision to trade on the exchange or over-the-counter we specify Equation (4) as follows:

$$\begin{aligned}\gamma'\omega_{I,n} = \gamma_0 &+ \gamma_1\text{Trade Size 10-30 million EUR}_n + \gamma_2\text{Trade Size} > \text{30 million EUR}_n \\ &+ \gamma_3\text{Round Trade Size}_n + \gamma_4\text{Inventory}_n + \gamma_5\text{Volatility}_n + \gamma_6\text{Dealer Volume}_n \\ &+ \gamma_7\text{Order Splitting}_n + \gamma_8\text{Aggregate Order Flow}_n + \gamma_9\text{Order Book Imbalance}_n \\ &+ \gamma_C\text{Controls}_n \quad . \end{aligned} \tag{7}$$

$\omega_{I,n}$ includes proxy variables for market and information frictions detailed in Section IV.B. To account for potential nonlinearities with respect to trade size, we employ dummy variables for trades of size 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, which capture bond-specific liquidity and bond characteristics. It includes *MTS half-spread*, which is half the bid-ask spread on MTS at the time of the trade, and *Depth at MTS best*, which is the logarithm of the volume available at the best level of the MTS order book on the side of the trade. *Cheapest-to-deliver* is a dummy variable that equals one for bonds that are cheapest-to-deliver for currently active futures contracts, and zero else.[24] *2-years Schatz*, *5-years Bobl* and *30-years Bund* are dummy variables that indicate a maturity at issuance of 2, 5, or 30 years, respectively. Hence, 10-year Bunds are the baseline securities. Further control variables account for issuance days (dummy), (logarithmic) amount outstanding, bond age (in percent of original maturity), the coupon rate (in percent), end-of-quarter effects (dummy) or end-of-year effects (dummy), on-the-run status (dummy), and whether the dealer is a German financial institution (dummy). Detailed definitions of all variables are provided in Table A.1. Throughout our analysis, all regressors except for dummy variables have been standardized to have mean zero and unit variance.

Specification (1) of Table III shows the marginal effects of the probit estimation, with standard errors clustered at the dealer level.

[Table III about here.]

The main results are as follows. Larger trades are less likely to be routed to the exchange, reflecting that in a limit order book transaction costs increase with trade size. Trades in the 10-30 million EUR range are, 2.7 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 11 percentage points more likely. We find evidence that over-the-counter trading is preferred when dealers have larger inventories. This effect is statistically significant but small. A one standard deviation increase in dealer inventory increases the likelihood of trading OTC by less than one percentage point. A possible explanation is that inventory concerns can partially be addressed via the futures or repo market.[25] The dummy variable

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[24] There exist futures contracts for 2-year Schaetze, 5-year Bobls and 10-year and 30-year Bunds, with most activity in the 10-year Bund futures. Trading activity is generally concentrated in the contract with the nearest delivery day, which is around the 10th of each March, June, September and December. Between three and five bonds are *deliverable* for each contract, one of these bonds being the *cheapest-to-deliver*. Its price is thus closely tied to the one of the futures via an arbitrage relationship. During our sample period the cheapest-to-deliver bond almost always coincided with the eligible bond with the nearest maturity date. It is worth pointing out that *physical delivery* of the futures on the delivery day is rare and most contracts are closed by entering an opposite position. This implies that, notwithstanding the comparatively more active futures market, anyone wanting to own Bunds, e.g. for regulatory reasons or to enter an arbitrage position, is active in the cash market.

[25] We have also considered alternative definitions of inventory, e.g. considering ISIN-specific inventory. The results are similar.

for volatile days is highly significant and implies that on such days trading on the exchange is 7.4 percentage points more likely, in line with the notion that the outside option of search in the OTC market is less feasible. We find no significant effect with respect to dealer volume. That is, larger dealers are, on average, not significantly more likely to trade on the exchange or OTC.

Transactions that have been split in smaller trades are 2.6 percentage points more likely to trade on MTS. This supports the prediction that informed traders prefer the exchange, in line with Seppi (1990); Grossman (1992); Lee and Wang (2017). While the coefficient for *Order Book Imbalance* is positive and statistically significant at the 10 percent level, the effect is economically small.

Market liquidity also plays an important role for venue choice. The MTS bid-ask spread is a highly significant driver; a one standard deviation increase in the half-spread reduces the probability that a trade is transacted on MTS by more than 8 percentage points. Reducing the volume available at the best by one standard deviation makes exchange trading about 1 percentage points less likely. Cheapest-to-deliver bonds (linked to the futures contract with very low bid-ask spreads) are on average 6.1 percentage points less likely to be traded on the exchange, and 30-year Bunds, which typically quote at considerably higher bid-ask spreads, are on average 15.5 percentage points more likely to be traded on the exchange. Both findings confirm the prediction of Lee and Wang (2017) that assets with wider bid-ask spreads are traded more often on exchanges.

Broker versus Bilateral OTC As discussed before the largest share of interdealer trading is done via brokers. We now analyze which trades are done via a broker or through bilateral negotiations. This decision is conditional on a trade not being executed on the exchange. We estimate the probit model in Equation (5), where the explanatory variables and controls are the same as in Equation (7) above, with the exception of the dummy for *Round Trade Size* which is no longer relevant. Column (2) of Table III shows the marginal effects of the probit estimation, with standard errors clustered at the dealer level.

Larger trades are significantly more likely to be routed via brokers. With respect to trades in the 2.5-10 million EUR range, OTC trades from 10-30 million EUR are 21 percentage points more likely transacted via a broker. This effect is even more pronounced for very large trades with a size larger than 30 million EUR, which are 37 percentage points more likely to be broker-intermediated, in line with the prediction of Bruche and Kuong (2019).

Dealers with larger inventories are more likely to trade via brokers. A one standard deviation increase in dealer inventory increases the likelihood of broker-intermediation by more than 2 percentage points. This indicates that in order to conceal information about their inventory position traders seek both anonymity and opacity. We find no evidence that volatility plays a role for this decision, as the dummy variable for volatile days is insignificant. The coefficient for dealer volume is significant and positive. That is, large dealers are more likely to trade via brokers than smaller ones. This finding is consistent with the notion that central dealers prefer to preserve their informational advantages about order flows or inventories and thus avoid trading directly with each other (Holland, 2001; Babus and Kondor, 2018).

Dealer informedness is a significant driver of the choice whether to trade via a broker or bilaterally. More informed trades, i.e. those that are part of order splitting, are 4.1 percentage points more likely to be routed via a broker than traded bilaterally. This suggests that dealers who value anonymity prefer to trade via brokers. The coefficient for aggregate order flow is positive and statistically significant at the 10% level, but the effect is economically small.

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

D. OTC Discount in Different Market Segments

In this section we document how market and information frictions affect OTC discount in bilateral and broker-facilitated Bund trades, controlling for venue choice. To this end we estimate Equation (6) separately for bilateral and broker OTC trades at the level of individual trades. In addition to the selectivity adjustments, the explanatory variables in Equation (6) are

$$\begin{aligned}\gamma' v_n = \; & \gamma_1 \text{Trade Size (log)}_n + \gamma_2 \text{Inventory}_n + \gamma_3 \text{Volatility}_n + \gamma_4 \text{Price Impact}_n \\ & + \gamma_5 \text{Order Splitting}_n + \gamma_6 \text{Aggregate Order Flow}_n + \gamma_7 \text{Order Book Imbalance}_n \\ & + \gamma_8 \text{MTS half-spread}_n + \gamma_9 \text{Depth at MTS best}_n + \gamma_b \Delta_b + \gamma_i \Delta_i + \gamma_C \text{Controls}_n \,, \end{aligned} \tag{8}$$

where Δ_b and Δ_i are bond- and (initiating) dealer-fixed effects, respectively, and *Controls* is a vector accounting for issuance days, cheapest-to-deliver and on-the-run status, bond age and end-of-quarter and end-of-year effects.

Bilaterally-negotiated Interdealer Trading. Table IV shows the estimation results using ordinary least squares. Standard errors are obtained via bootstrap to account for correlation with protocol choice.[26] Specification (1) reports the estimations for bilaterally negotiated OTC trades between MTS dealers.[27]

[Table IV about here.]

The results can be summarized as follows. The OTC discount decreases with trade size, i.e. larger trades receive lower OTC discounts. A one standard deviation increase in trade size leads to a reduction of OTC discount by almost 6 percentage points. This is consistent with the notion that for larger trades the exchange no longer represents a feasible outside option, and thus the bargaining position for such trades is impaired. That

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[26] Specifically, we draw 1,000 samples of the same number of trades with replacement from our set of trades. For each sample we repeat the protocol choice and the OTC discount estimations, and obtain standard errors from the distribution of coefficient estimates.

[27] We deem very large OTC premia as unrealistic and winsorize OTC discount from below at -100%. Our results are robust to omitting this cleaning step.

said, it runs contrary to observations for pure OTC markets, where transaction costs typically decrease with trade size (Edwards, Harris, and Piwowar, 2007; O'Hara and Zhou, 2020).

A one standard deviation increase in the absolute inventory level of a dealer in a given security significantly reduces their OTC discount by about one percentage point. This is consistent with the notion that dealers with higher inventories have lower bargaining power. On the 10% most volatile days, when the outside option of continued search is more costly or less feasible, OTC discount is 21.5 percentage points lower for bilateral OTC trades. This effect is significant and sizeable compared to an average OTC discount of 54.6 percentage points for bilateral trades. Hence, volatility is important for the relative pricing on the exchange as compared to the OTC segment.

As an alternative to trade-specific measures of bargaining power, we can also assess the individual bargaining power of different dealers by including dealer fixed effects. Since we control for a host of other confounding effects, differences in the fixed effects should to a large extent reflect dealers' differential bargaining power. Dealer fixed effects differ markedly: their standard deviation across dealers is 17.6 percentage points of the MTS half-spread in specification (1) – almost one third of average OTC discount. We interpret this dispersion of dealer-fixed effects as representing a significant heterogeneity of dealers' bargaining power.

To illustrate the effect of dealer-specific bargaining power further, we construct dummy variables for the top and bottom five dealers in terms of their dealer-fixed effects in specification (1). In specification (2) we repeat the estimation, where now we include these dummies and exclude dealer-fixed effects. In bilateral interdealer trades the top five dealers receive an almost 9 percentage points higher OTC discount than their peers, while the bottom five receive a 37.5 percentage points lower OTC discount. These effects are sizeable, given that the average OTC discount is 54.6 percentage points. This suggests that dealer-specific bargaining power plays a quantitatively important role for OTC discount, over and above the proxies included in our regressions.

Looking at measures of information frictions we see that informed trades receive a lower OTC discount. Both price impact after 15 minutes and order splitting are associated with a lower OTC discount.[28] A one standard deviation increase in price impact corresponds to a 2.4 percentage points lower OTC discount. Trades that are part of an order splitting strategy receive a 5.2 percentage points lower discount. This is in line with the predictions from information-based models and indicates that dealers are price discriminating against each other when trading bilaterally because they can infer each other's informedness.

Trading in the same direction as the overall market (i.e. when aggregate order flow is positive) lowers OTC discount. For example, for a buy trade a one standard deviation increase in net Bund purchases on the same day prior to the trade, implies that the OTC discount is 1 percentage point lower for bilateral trades. We do not, however, observe such an effect relating to the order book imbalance.

We also control for market liquidity on the exchange using the MTS half-spread and depth at the best level of the MTS order book (on the respective side of the trade). In all specifications MTS half-spread is a significant driver of OTC discount: the larger the bid-ask spread, the higher is the average OTC discount. This effect is partly mechanical due to the normalization of OTC discount. But it also reflects that a deterioration of liquidity conditions on the exchange is only partially passed on to the OTC segment.

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

Broker-intermediated Interdealer Trading. Specification (3) in Table IV shows the estimation results for interdealer trades intermediated by brokers. In general, the estimated coefficients have the same sign as for bilaterally-negotiated trades, but differ

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[28] We have verified that our results don't 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.

somewhat in magnitude. Hence, the same frictions drive the relative trading costs of bilaterally negotiated and broker-intermediated trades, albeit to varying degrees.

A one standard deviation increase in trade size leads to a reduction of OTC discount by about 3 percentage points. This is half the effect of bilateral trades, suggesting that trade size does not matter as much for the pricing of broker-intermediated trades which also tend to be substantially larger. The estimation coefficient for inventory is insignificant and smaller in absolute magnitude than for bilateral trades. Given that larger inventories also imply a higher probability of trading via brokers (Table III), this might suggest that the smaller price sensitivity of trading via brokers to inventories is a feature that is attractive to dealers. On the 10% most volatile days, OTC discount is about 21 percentage points lower, and thus comparable to bilateral trades.

For broker-intermediated trades a one standard deviation higher price impact corresponds to a one percentage point lower OTC discount. Trades that are part of an order splitting strategy receive, on average, a 4.9 percentage points lower discount. The coefficients for our informedness proxies are thus lower for broker-intermediated trades, suggesting that the trading costs of broker-intermediated trades – wich are more opaque as they hide the counterparty – are less sensitive to informed trading. Trading in the same direction as the order flow is associated with a lower OTC discount. A one standard deviation lower aggregate order flow implies a 2.6 percentage points lower OTC discount for broker-facilitated trades. This is about twice the estimated effect for bilaterally negotiated interdealer trades. A possible interpretation of this finding is that broker trades obscure counterparty-specific informedness while information on aggregate order flow is preserved. The importance of the latter channel thus increases for broker trades.

In sum, while the driving forces of OTC discount tend to be the same across the two protocols, there are some meaningful quantitative differences. We next analyze these differences in more detail.

Differences between OTC Protocols. Interestingly, the differences in how market and information frictions affect OTC discount in bilaterally-negotiated versus broker-facilitated trades do not explain the sizable unconditional differences in OTC discount across the two trading protocols documented in Section III.A. This can be seen by comparing the estimated intercepts across specifications (1) and (3) in Table IV. They imply a difference in OTC discount of 18.4 percentage points that is unexplained by the market and information friction proxies.

This is surprising in light of the fact that 78% of the transaction volume in the D2D segment are routed via brokers. We therefore aim to corroborate this finding with two alternative approaches. First, we use the coefficients of Equation (6) for the drivers of OTC discount (specifications (1) and (3) in Table IV) to construct a predictor for OTC discount given trades' characteristics. That is, we compute for each bilaterally negotiated trade the predicted OTC discount it would have received had it been intermediated via broker. Similarly we compute the predicted OTC discount the broker-intermediated trades in our sample would have received if they had been bilaterally negotiated. We then calculate the difference between the hypothetical predicted OTC discount using one protocol and the realized observed OTC discount using the other protocol for each trade. The average of this difference is 18.2 percentage points and statistically significant at the 1% level.

Second, we construct a sample of trades that differ in the trading protocol but are otherwise similar. Specifically, we construct a matched sample that pairs bilaterally negotiated trades with similar broker transactions using "nearest neighbor" propensity score matching. The variables used in the matching procedure are the MTS bid-ask spread and depth, (logarithmic) trade size, the date, bond identifier, the identity of the initiating dealer, the direction of the trade, volatility, inventory, order flow, and dummy variables for whether a bond was issued or reopened on the same day, its status as cheapest-to-deliver bond in the current futures contract, on-the-run status and end-of-quarter and end-of-year effects. We enforce strict matching on the bond and dealer dimension, 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 dealers' full trading activity. We then estimate the following equation:

$$OTC\ discount_n = \gamma' v_n + \varepsilon_n \,. \tag{9}$$

Since our sample by construction consists of similar trades, there are no selectivity corrections as in Equation (6). v, in addition to the variables described in Equation (8), contains a dummy variable indicating trades via brokers, i.e.

$$\begin{aligned} \gamma' v_n = \; & \gamma_1 \text{Trade via broker}_n + \gamma_2 \text{Trade Size (log)}_n + \gamma_3 \text{Inventory}_n + \gamma_4 \text{Volatility}_n \\ & + \gamma_5 \text{Price Impact}_n + \gamma_6 \text{Order Splitting}_n + \gamma_7 \text{Aggregate Order Flow}_n \\ & + \gamma_8 \text{Order Book Imbalance}_n + \gamma_9 \text{MTS half-spread}_n \\ & + \gamma_{10} \text{Depth at MTS best}_n + \gamma_b \Delta_b + \gamma_i \Delta_i + \gamma_C \text{Controls}_n \quad , \end{aligned} \tag{10}$$

where *Trade via broker* takes the value of 1 for broker trades and 0 for bilaterally negotiated OTC trades. Δ_b and Δ_i are bond- and (initiating) dealer-fixed effects, respectively, and controls not shown account for issuance days, cheapest-to-deliver and on-the-run status, bond age and end-of-quarter and end-of-year effects.

[**Table V about here.**]

Table V shows the results of estimating Equation (9) using the matched sample described above. The main result is that broker-facilitated trades have an OTC discount that is about 15 percentage points lower than bilaterally negotiated trades. While this is a bit smaller than the 18 percentage point difference obtained using the other two approaches, it highlights that broker trades receive a substantially lower OTC discount than bilaterally negotiated trades. In fact, given that the average OTC discount of bilateral interdealer trades reported in Table II is about 55 percentage points, broker trades are more than 25% more expensive than corresponding bilaterally negotiated trades.[29]

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[29] The estimation coefficient is in line with the average difference in OTC discount between bilateral and broker trades of 30.0 percentage points as reported in Table II, but controls for trade characteristics. The effect we find is also considerably larger than broker fees, which are of the order of 0.15 basis points, see the rate card for European government bonds of the interdealer broker Tradition, available at `https://www.tradition.co.uk/about-us/compliance/documents/other.aspx`.

If trading costs do not explain the prevalence of broker intermediation, what does? One dimension that dealers might care about is their price impact (see, e.g. Keim and Madhavan (1997)). To see if the price impact in both protocols is different and potentially a reason for the differences in trading costs we compute the average price response of MTS mid-quotes to trades in each protocol, which we define as

$$R_h^s = \mathbb{E}\left[\left(X_{t+h-\varepsilon} - X_{t-\varepsilon} \right) \epsilon_t^s | \mathbb{1}_{\text{Trade}_t^s} \right], \tag{11}$$

where X_t is the log MTS mid-price of bond i at time t and ϵ_t^s is the order sign of the trade ($+1$ for buys, -1 for sells) which occurred at time t using the trading protocol $s \in \{\text{MTS}, \text{bilateral}, \text{broker}\}$. That is R_h^s represents the average logarithmic return over the horizon h, conditioning on a trade in protocol s.

[Figure 3 about here.]

Figure 3 shows the evolution of R_h^s for trades of at least 2.5 million EUR in 10-year Bunds in response to exchange, bilateral and broker OTC trades over a horizon of up to one hour. The average response to exchange trades is largest. Prices jump instantaneously, reach their peak of about 1.3 basis points above the previous trade price after about ten minutes, and move sideways afterwards. The average response to bilateral OTC trades is considerably smaller than for exchange trades. It is 0.2 basis points in the minute after the trade and then slowly increases to about 0.6 basis points one hour after the trade. Broker trades have essentially no price impact.[30]

The large and immediate response on the exchange is likely related to two factors. First, a trade on the exchange might cause a mechanical impact on the mid-price when depleting the best level(s) of the limit order book. Second, any exchange trade can be observed by other market participants who may adjust their quotes accordingly.[31]

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[30] The results are very similar for other securities. An important driver of price impact is trade size. Accounting for a linear dependence on trade size (i.e. calculating the price impact per million EUR traded) yields an even more pronounced difference in price impact across protocols, since average trade sizes increase from exchange to bilateral OTC to broker trades, see Table I.

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

Bilateral OTC trades are instead observed only by the two parties involved. Therefore, it is unsurprising that information from the trade is disseminated much more slowly across the market. The smaller response suggests a lower informational content of bilateral OTC trades, in line with information-based models of hybrid markets.

Strikingly, the average response to broker trades is essentially zero. This suggests that trades via brokers are either, on average, less informed, or that the interdealer broker protocol is an effective means to prevent the diffusion of information contained in trades. Our finding that interdealer trading via brokers is associated with both lower OTC discount and lower price impact suggests that dealers value the opacity provided by interdealer brokers. They are willing to forego a share of OTC discount in order to reduce the price impact and visibility of their trading. This is in line with dealers' desire to protect themselves against price revision risk (Naik, Neuberger, and Viswanathan, 1999), predation risk due to frontrunning (Harris, 1997), or predatory trading by other dealers (Brunnermeier and Pedersen, 2005). By providing opacity about the identities of involved counterparties as well as about the occurrence of trades, interdealer brokers alleviate the above issues.

E. The Dealer-to-Customer Segment

In the previous sections we have documented the existence and prevalence of an OTC discount in interdealer Bund trading and have studied its drivers. 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-customer relationship, while controlling for market and information frictions. As in the interdealer segment we use OTC discount as defined in equation (2) as our variable of interest, where the contemporaneous price on MTS is no longer an attainable outside option for customers but serves as a reference price that is easily observable to clients.[32]

We measure the importance of the dealer-customer relationship with two variables: the dealer's bargaining power in the D2D segment and the value of the relationship to the customer. For dealers' bargaining power we use the dealer fixed effects (FE) obtained from estimating Equation (6) for bilateral interdealer trades (specification (1) of Table IV). 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 also 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.

To account for dealer-client relationships we employ the *overall volume of the dealer-client pair*. The larger the overall trade volume of such a pair, the more valuable is the relationship for both parties. We expect dealers to provide higher discounts to regular clients to maintain the relationship, i.e. we expect a positive coefficient also here.

Formally we estimate

$$OTC\ discount_n = \gamma' v_n + \varepsilon_n, \tag{12}$$

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[32] Yields of benchmark bonds are published in real-time on `https://www.mtsmarkets.com/european-bond-spreads`. Subscriptions services such as Bloomberg allow access to MTS prices and volumes at the best bid and ask levels in real time, also for non-MTS dealers.

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

$$\begin{aligned}\gamma' v_n = \; & \gamma_1 \text{Trade Size (log)}_n + \gamma_2 \text{Volatility}_n + \gamma_3 \text{Price Impact}_n + \gamma_4 \text{Order Splitting}_n \\ & + \gamma_5 \text{Aggregate Order Flow}_n + \gamma_6 \text{Order Book Imbalance}_n \\ & + \gamma_7 \text{MTS half-spread}_n + \gamma_8 \text{Depth at MTS best}_n \\ & + \gamma_D \text{Dealer-client characteristics}_n + \gamma_b \Delta_b + \gamma_j \Delta_j + \gamma_C \text{Controls}_n \quad . \end{aligned} \tag{13}$$

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-client characteristics* are the proxies measuring the dealer-customer relationship as outlined above, i.e. the *Dealer FE (D2D)*, *overall trade volume (dealer)*, and *overall volume of the dealer-client pair.*

[Table VI about here.]

Table VI 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 VI 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 lower for larger trades, when volatility is high, and for trades against the aggregate order flow of the market. Similarly, OTC discount is smaller for trades with a larger price impact and in the presence of order splitting. OTC discount is larger when bid-ask spreads on MTS are wider and when the order book of MTS is deeper. 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), (3), and (4) additionally include dealer bargaining power, overall dealer volume, and overall volume of the dealer-client pair, respectively. The estimation coefficients for these variables are positive and significant across all specifications, implying that customers benefit from trading with dealers with more bargaining power in the D2D segment, and from a stronger relationship with such a dealer. An improvement in the dealers FE from bilateral interdealer trading by one standard deviation corresponds to an average increase in OTC discount for the client by 2.1 percentage points. Also when we consider the dealer bargaining power and dealer-client volume jointly in specification (5), both effects prevail.

Our results are robust with respect to several important dimensions, and we present the corresponding robustness analyses in the Appendix. First, we lower the minimum trade size for the D2C segment to 100,000 EUR thereby substantially increasing the number of trades. Second, we consider also D2C trades where we are unable to reliably trace customers across trades. All results are quantitatively and qualitatively in line with those presented here.

It is interesting to compare our finding to Li and Schürhoff (2019) who find that in the U.S. municipal bond market more central dealers charge investors higher transaction costs, but also provide more immediacy. In our view, this reflects the microstructure of the municipal bond interdealer market as a pure OTC market where centrality plays a key role for the provision of immediacy implying that only the most central dealers can provide a high degree of immediacy. In contrast, the hybrid D2D Bund market structure gives all dealers virtually the same access to immediacy through the exchange, and thus mutes the effects of speed differentials on D2C liquidity provision and transaction costs.

In the absence of such differentials, 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 in turn enabling them to offer better quotes in D2C segment, which again lead 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.

V. Conclusion

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

In this paper we contribute to this understanding along several dimensions. Using a unique regulatory dataset of securities transactions, we study price differences across trading protocols and market segments in the German Bund market. Our main finding is that the vast majority of OTC trades execute at favorable prices relative to the interdealer limit order book. We show that the magnitude of this OTC discount in bilateral trades is driven by both market and information frictions, reflecting the bargaining position of dealers and their perceived informedness. Exploring venue choice, we document that dealers are more likely to execute a trade on the exchange when volatility is high, and for less liquid bonds. Hence, the exchange acts as an outside option and as a potential provider of "liquidity-of-last-resort".

That said, we find that interdealer brokers account for more than three quarters of interdealer trading volume, despite the fact that broker-intermediated receive lower discounts than comparable bilateral trades. As trades routed via brokers are larger on average and do not feature discernible price impact, we interpret their role as providing opacity and insurance against price revision risk.

Pricing in the dealer-to-customer market is driven by the same market and information frictions that are important in the D2D segment. In addition, a dealer's position in the D2D market affect the pass-through of discount, thus implying that market structure and trading conditions in the interdealer market matter for the market as a whole.

These results are relevant for the current regulatory debate. There is a strong effort to improve OTC market transparency both in Europe, where the MiFID II regulation was recently rolled out with the intention to improve market conditions in and beyond European markets and in the U.S., where FINRA has started to collect data similar to that in the TRACE database also for sovereign bonds. Our results suggest that OTC and exchange as well as broker-intermediated trading play complementary roles in serving the different needs of dealers in a way that a single venue might not be able to achieve. As pointed out by Dugast, Üslü, and Weill (2019), even if a centralized exchange market is socially optimal, agents' decisions for trading protocols are driven by their private incentives. While our empirical analysis cannot shed light on the socially optimal market structure, our results provide novel insights for theoretical studies addressing this important question and for the regulation of fixed-income trading.

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Figures

Figure 1. Trade Sign and OTC Discount: We classify OTC trades above (below) the quoted mid-price on MTS as buyer- (seller-) initiated. For a buyer-initiated trade *OTC discount* is the price difference between the quoted best ask price on MTS and the actually observed price of the trade, normalized by the MTS half-spread, i.e. 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, i.e. when trading on MTS would have been cheaper. Trades at the mid-price have 100% OTC discount, whereas buys at the MTS ask price and sells at the MTS bid price have 0% OTC discount, i.e. the OTC trade presented no price improvement over MTS.

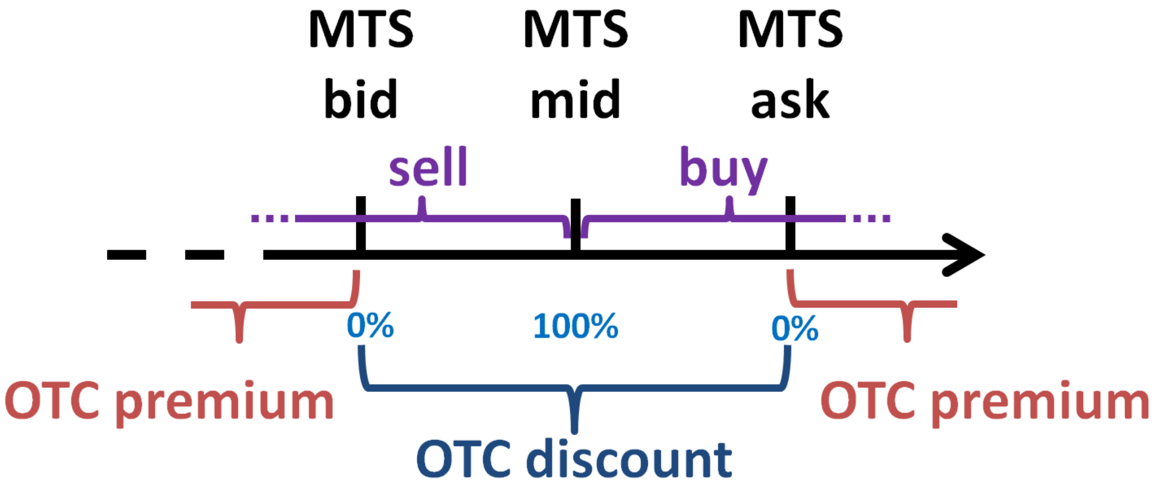
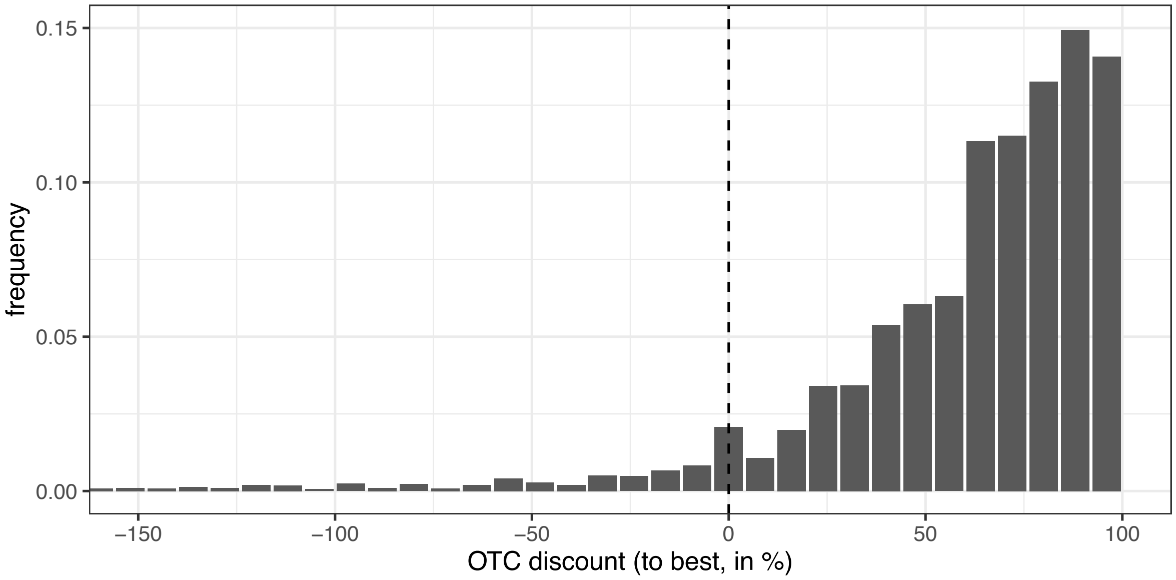
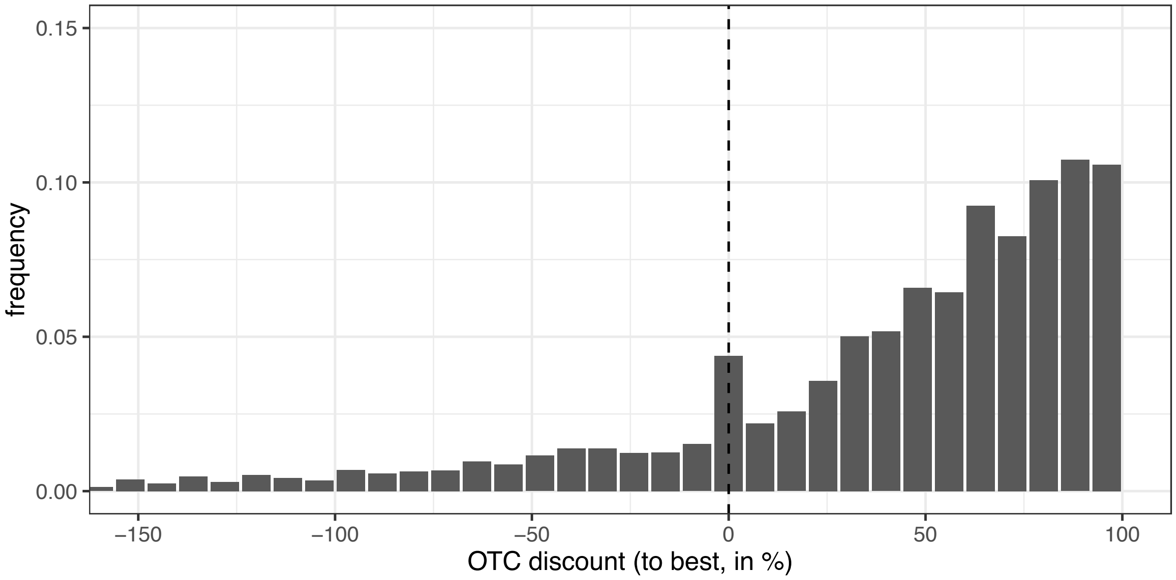


Figure 2. Histogram of OTC Discount: *OTC discount*, defined in Equation (2) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, normalized by the MTS half-spread. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. OTC discount is bounded from above to be 100%, at most. The figure shows the distribution of OTC discount based on interdealer trades of nominal size of at least 2.5 million EUR. Panel (a) refers to bilateral OTC trades and Panel (b) to trades via a broker. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

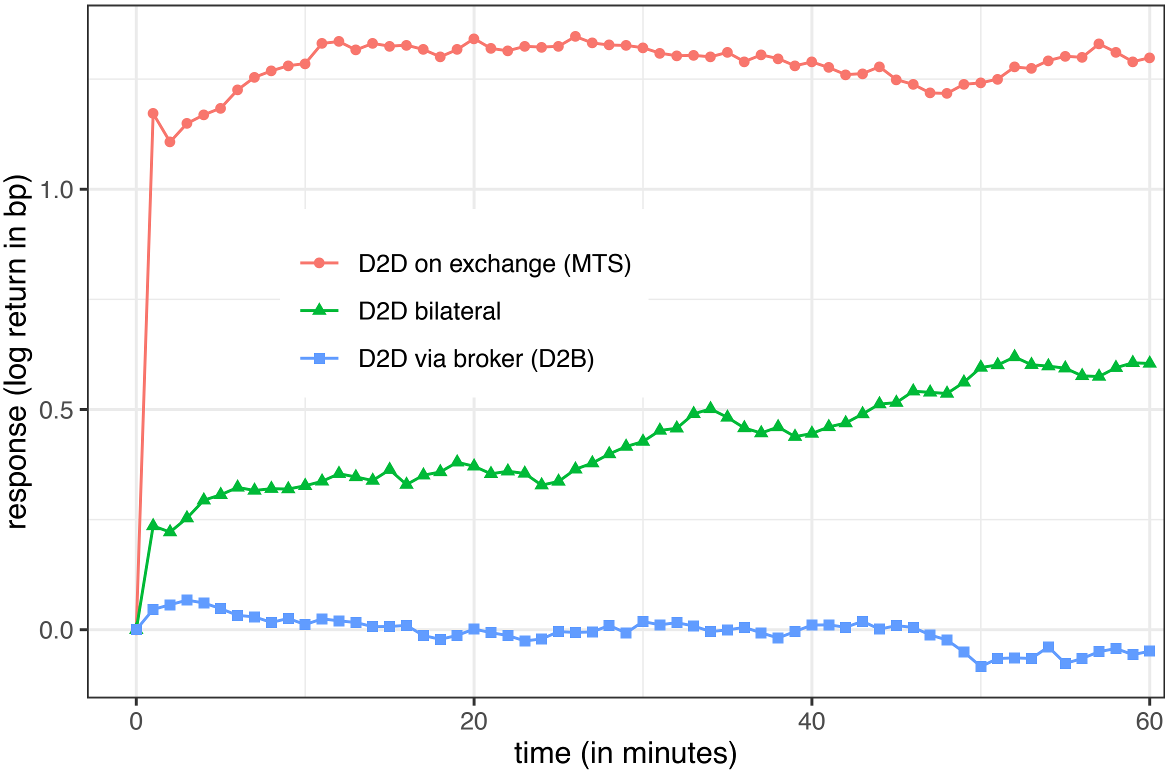


(a) Interdealer trades via bilateral OTC.



(b) Interdealer trades via broker.

Figure 3. Price Impact across Segments: Response function to interdealer trades in the exchange and OTC segments. The response function R_h^s is defined as $R_h^s = \mathbb{E}\left[\left(X_{t+h-\varepsilon} - X_{t-\varepsilon}\right)\epsilon_t^s | \mathbb{1}_{\text{Trade}_t^s}\right]$, where X_t is the log MTS mid-price of bond i at time t and ϵ_t^s is the order sign of the trade (+1 for buys, −1 for sells) which occurred at time t via protocol $s \in \{\text{MTS}, \text{bilateral OTC}, \text{broker}\}$. R_h^s thus represents the logarithmic return over horizon h, conditioning on a trade via protocol s. The figure shows the response of 10-year Bunds to D2D trades for a nominal amount of at least 2.5 million EUR. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.



Tables

Table I. Trading Activity by Subsamples: This table provides an overview of trading activity for the full sample of observed trades and the subsamples used in our analysis. *Full sample* refers to the cleaned and unfiltered sample, and *init. & counterp. ID known* to those trades where both parties are identified. In the interdealer segment (labeled *D2D*) we consider the subset of all trades with a nominal amount of at least 2.5 million EUR (*trade size* $\geq$ *2.5 million EUR*) and distinguish by trading protocol: *D2D via MTS*, i.e. trades on the interdealer exchange MTS, *D2D via bilateral OTC*, i.e. bilaterally negotiated interdealer trades, and *D2D via broker (D2B)*, i.e. interdealer trades intermediated by an interdealer broker. 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 II.C). Reported are the number of trades for each subsample, the aggregated trade volume over our full sample period, the volume share of overall interdealer volume, and summary statistics of trade size (in terms of notional amount). Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

	# trades	trade volume		trade size						
		sum (billion EUR)	share of D2D (%)	Mean	Std Dev	5 Pcl	25 Pcl (million EUR)	Median	75 Pcl	95 Pcl
full sample	503,220	3,395.39		6.75	19.46	0.00	0.10	1.00	5.00	30.00
init. & counterp. ID known	211,886	1,485.02		7.01	17.35	0.01	0.18	1.25	5.00	32.50
D2D	47,449	493.55		10.40	19.95	0.10	0.90	2.00	10.00	50.00
trade size $\geq$ 2.5 million EUR	22,252	470.13	100.00	21.13	25.13	2.75	5.00	10.00	25.00	72.00
D2D via MTS	2,179	17.18	3.65	7.88	6.40	2.50	5.00	5.00	10.00	13.00
D2D via bilateral OTC	6,791	86.52	18.40	12.74	20.30	2.60	3.80	5.40	11.60	50.00
D2D via broker (D2B)	13,282	366.43	77.94	27.59	27.09	3.00	7.00	20.00	40.00	85.00
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

Table II. Descriptive Statistics of OTC Discount: *OTC discount*, defined in Equation (2) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, normalized by the MTS half-spread. It is given in percentage points. A positive OTC discount implies that executing a trade over-the-counter is cheaper for the initiator than trading on the exchange. Reported are summary statistics of OTC discount for the subsets defined in Table I, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. The column p-value refers to a t-test of the mean being different from zero and *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,018	35.85	105.89	-109.50	32.00	65.71	84.00	96.23	13.5	0.0000
init. & counterp. ID known	209,427	45.91	72.69	-74.39	36.67	66.67	85.00	96.47	11.3	0.0000
D2D	45,032	39.97	82.05	-100.00	32.00	65.33	84.00	96.25	13.2	0.0000
trade size $\geq$ 2.5 million EUR	20,073	34.71	87.29	-125.25	25.00	61.60	82.35	96.00	15.8	0.0000
D2D via bilateral OTC	6,708	54.57	60.44	-25.00	45.71	70.00	85.71	96.00	6.9	0.0000
D2D via broker (D2B)	13,226	24.60	96.44	-160.47	9.52	55.50	80.00	95.65	20.4	0.0000
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 III. Probability Model for Protocol Choice: Marginal effects at means of a probit model. In specification (1) we estimate $Pr(OTC_n|\omega_n) = \Phi(\gamma'\omega_n)$, where OTC_n is a dummy variable that takes the value of one when the trade protocol for transaction n is either bilaterally negotiated or broker intermediated, and zero when it is MTS. In specification (2) we estimate $Pr(Broker_n|OTC_n, \omega_n) = \Phi(\gamma'\omega_n)$, where $Broker_n$ is a dummy variable that takes the value of one when the trade protocol for transaction n is broker intermediated, and zero when it is bilaterally negotiated. Φ is the standard normal cumulative distribution function and ω_n is a vector of variables representing market and information frictions and control variables, as detailed in Equation (7), cf. section IV.C. The sample consists of interdealer trades for a minimum trade size of 2.5 million EUR (rows *D2D via MTS*, *D2D via bilateral OTC*, and *D2D via broker (D2B)* in Table I for specification (1) and rows *D2D via bilateral OTC*, and *D2D via broker (D2B)* for specification (2)). Based on transactions data including all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Z-scores are given in brackets where standard errors are clustered at the dealer level and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Interdealer trades:	OTC vs. MTS	broker vs. bilat. | OTC
	(1)	(2)
Trade size 10-30 million EUR (dummy)	0.0270**	0.2091***
	(2.2534)	(4.1183)
Trade size > 30 million EUR (dummy)	0.1078***	0.3702***
	(4.1807)	(7.6943)
Round trade size (2.5/5/10 mn EUR, dummy)	-0.1701***	
	(-9.5403)	
Inventory	0.0080***	0.0229***
	(3.1311)	(3.1435)
Volatility (dummy)	-0.0740***	0.0239
	(-7.1942)	(1.0758)
Dealer Volume (tn EUR)	-0.0182	0.1468***
	(-0.9038)	(2.8344)
Order splitting (dummy)	-0.0256***	0.0410***
	(-3.8985)	(2.7569)
Aggregate order flow (bn EUR)	0.0040	0.0085*
	(1.4808)	(1.7235)
Order book imbalance (mn EUR)	0.0035*	-0.0044
	(1.9093)	(-1.6251)
MTS half-spread (bp)	0.0816***	-0.0240**
	(8.6824)	(-2.3441)
Depth at MTS best (log)	-0.0094***	0.0143***
	(-4.2152)	(4.2859)
Cheapest-to-deliver (dummy)	0.0607***	0.0984***
	(5.8214)	(6.1922)
2-years Schatz (dummy)	-0.0808***	-0.0796
	(-8.0481)	(-1.6213)
5-years Bobl (dummy)	-0.0219***	-0.0159
	(-2.7393)	(-0.4652)
30-years Bund (dummy)	-0.1548***	0.2472***
	(-6.3242)	(3.9213)
R^2_{pseudo}	0.4106	0.1871
N	22,234	20,058
Controls	yes	yes

Table IV. Intermediation Frictions and OTC Discount : 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 (6) and Section IV.D). The dependent variable, *OTC discount*, defined in Equation (2) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, normalized by the MTS half-spread. v_n, as detailed in Equation (8), is a vector of variables representing market and information frictions, and containing control variables, including fixed effects for bond and initiating dealer respectively. λ^{OTC} and λ^{s}, $\mathrm{s} \in \{bilateral, broker\}$, 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 I) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker (D2B)* in Table I). The minimum trade size is 2.5 million EUR in all specifications. Based on transactions data including all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are obtained through sampling. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Interdealer trading protocol:	bilateral OTC		via broker
	(1)	(2)	(3)
Trade size (log)	-5.8020***	-7.3109***	-3.0847***
	(-3.7952)	(-8.2137)	(-2.7633)
Inventory	-1.1120**	-1.0142**	-0.4909
	(-2.0799)	(-2.0915)	(-0.9691)
Volatility (dummy)	-21.5452***	-21.8806***	-20.6458***
	(-6.0572)	(-6.0913)	(-7.4180)
Top 5 dealer (dummy)		8.9271***	
		(6.4582)	
Bottom 5 dealer (dummy)		-37.5277***	
		(-3.5137)	
Price impact (15min, in bp)	-2.4152***	-2.3476***	-0.9783*
	(-3.0909)	(-3.0064)	(-1.9118)
Order splitting (dummy)	-5.1934***	-5.6486***	-4.9295***
	(-3.7179)	(-4.2225)	(-4.4290)
Aggregate order flow (bn EUR)	-0.9785**	-0.9450*	-2.6205***
	(-2.0101)	(-1.9360)	(-5.3961)
Order book imbalance (mn EUR)	0.1490	0.2641	0.6957
	(0.2221)	(0.4017)	(1.2019)
MTS half-spread (bp)	16.5123***	16.9600***	16.5536***
	(11.0763)	(11.8843)	(16.1658)
Depth at MTS best (log)	0.7983	0.5129	0.9520
	(1.3968)	(0.9107)	(1.5976)
Inv. Mills OTC	-1.3145*	-1.1029	-0.0169
	(-1.8202)	(-1.5375)	(-0.0223)
Inv. Mills Bilateral	1.8471	-0.1257	
	(0.8133)	(-0.1055)	
Inv. Mills Broker			-6.8406***
			(-4.3352)
Intercept	57.8161***	57.5086***	39.3970***
	(45.7221)	(53.8422)	(48.5954)
R^2	0.1300	0.1170	0.2023
R^2_{adjusted}	0.1078	0.0989	0.1934
R^2_{within}	0.0703	0.0823	0.0633
N	6,578	6,578	12,947
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Table V. Differences in OTC Discount across Interdealer Protocols: OLS Estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ (cf. Equation (9) and Section IV.D). The dependent variable, *OTC discount*, defined in Equation (2) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, normalized by the MTS half-spread. v_n, as detailed in Equation (10), 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 market and information frictions, as well as control variables, including fixed effects for bond and initiating dealer respectively. 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 IV.D. The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, dealer and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

	(1)	(2)
Trade via broker (dummy)	-14.9535***	-14.3539***
	(-7.3935)	(-5.6969)
Trade size (log)		0.6967
		(0.4593)
Inventory		-0.1535
		(-0.1668)
Volatility (dummy)		-7.5521
		(-1.9195)
Price impact (15min, in bp)		0.4434
		(0.4906)
Order splitting (dummy)		-4.0445*
		(-2.3819)
Aggregate order flow (bn EUR)		-1.7081*
		(-2.2389)
Order book imbalance (mn EUR)		-0.4697
		(-0.7895)
MTS half-spread (bp)		9.7961***
		(5.3120)
Depth at MTS best (log)		0.4383
		(0.5333)
R^2	0.0975	0.1290
R^2_{adjusted}	0.0725	0.1016
R^2_{within}	0.0368	0.0704
N	4,194	4,194
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table VI. OTC Discount in the D2C segment. OLS Estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ on dealer-to-customer trades (cf. Equation (12) and Section IV.E). The dependent variable, *OTC discount*, defined in Equation (2) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, normalized by the MTS half-spread. v_n, as detailed in Equation (13), is a vector of trade and bond characteristics proxying for market and information frictions, dealer-client characteristics, and containing control variables, including fixed effects for bond and initiating customer respectively. The sample consists of bilateral OTC trades between dealers and customers, where the dealer is a reporting entity to our transactions data and the trade was initiated by the customer (row *D2C – customer-initiated* in Table I). The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, customer, and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)	(5)
Trade size (log)	-5.3779***	-5.3849***	-5.3131***	-5.5858***	-5.5927***
	(-5.6986)	(-5.7056)	(-5.6437)	(-6.0162)	(-6.0275)
Volatility (dummy)	-11.1593***	-11.0892***	-11.0550***	-11.1442***	-11.0742***
	(-5.6884)	(-5.6858)	(-5.6066)	(-5.7346)	(-5.7289)
Price impact (15min, in bp)	-1.1326*	-1.1188*	-1.1281*	-1.1332*	-1.1194*
	(-1.7742)	(-1.7549)	(-1.7700)	(-1.7656)	(-1.7459)
Order splitting (dummy)	-4.1349***	-4.1664***	-4.2827***	-4.1281***	-4.1595***
	(-3.0464)	(-3.0838)	(-3.1813)	(-3.0273)	(-3.0634)
Aggregate order flow (bn EUR)	-1.4999***	-1.5000***	-1.4951***	-1.4848***	-1.4849***
	(-3.0364)	(-3.0503)	(-3.0332)	(-3.0207)	(-3.0345)
Order book imbalance (mn EUR)	0.0028	0.0032	0.0009	0.0036	0.0040
	(0.0824)	(0.0944)	(0.0261)	(0.1072)	(0.1191)
MTS half-spread (bp)	11.5186***	11.5424***	11.6554***	11.5530***	11.5768***
	(6.9981)	(7.0033)	(7.0441)	(7.0578)	(7.0655)
Depth at MTS best (log)	1.7426***	1.7574***	1.7685***	1.7411***	1.7559***
	(3.6126)	(3.6335)	(3.6760)	(3.6462)	(3.6688)
Dealer FE (D2D)		2.0970***			2.0949***
		(2.8213)			(2.8574)
Overall trade volume (dealer)			2.3760***		
			(3.1594)		
Overall volume of the dealer-client pair				13.4635***	13.4589***
				(4.0121)	(4.0874)
R^2	0.2890	0.2896	0.2898	0.2906	0.2911
R^2_{adjusted}	0.2597	0.2602	0.2605	0.2613	0.2618
R^2_{within}	0.0342	0.0349	0.0352	0.0363	0.0370
N	12,710	12,710	12,710	12,710	12,710
Bond FE	yes	yes	yes	yes	yes
Customer FE	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes

Appendix

accompanying

OTC Discount

December 7, 2020

Appendix A. Descriptive Statistics of Explanatory Variables

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

[Tables A.1 and A.2 about here.]

Appendix B. Alternative Definitions of OTC Discount

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

Walking Up The Book. First, we explicitly account for the feature of exchange markets that trades larger than the quantity quoted at the respective best level of the limit order book also consume liquidity from deeper levels of the limit order book. This implies that such trades automatically incur higher transaction costs and is often referred to as "walking up the book". In practice, traders 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 an alternative specification that takes into account the effects of walking up the book here.

To this end, we re-visit the definition of OTC discount (Equation (2) in Section III):

$$OTC\ discount = \frac{\epsilon\left(price^{\text{virtual,MTS}} - price^{\text{observed, OTC}}\right)}{\left\|price^{\text{virtual,MTS}} - price^{\text{mid,MTS}}\right\|} \quad , \tag{B1}$$

and we re-define OTC discount to take into account the full state of the limit order book. To this end, $price^{\text{virtual,MTS}}$ is no longer the price at the respective best level but takes into account the complete depth of the full limit order book.[33]

[Table A.3 about here.]

Table A.3 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 II). This is a mechanical effect due to our updated definition. Since for larger trades the comparison transaction cost on MTS becomes higher, the discount of OTC trades (which remains unchanged) with respect to this comparison increases. Relatedly, also the share of OTC trades at an OTC premium is smaller as size effects are taken into account, and this reduction of OTC premia is especially strong for broker trades that are, on average, larger. The average OTC discount of bilateral interdealer trades is now 61.6% and 46.6% for interdealer trades via brokers.

[Table A.4 about here.]

Table A.4 presents the results of estimating Equation (6) with OTC discount as defined in Equation (B1) as the dependent variable. Most results are similar to those presented in the main text and we focus here on the differences. The most notable change 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. For very volatile bond-days we find a slightly weaker effect than

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[33] That is, $price^{\text{virtual,MTS}}$ 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.

in the main specifications. On those days, bilateral and broker OTC interdealer trades respectively receive 20.9 and 18.9 percentage points OTC discount less, on average. The estimation coefficients for aggregate order flow is significant only for broker trades and we do not observe a significant effect for inventory. The estimation coefficient for inventory is in line with our previous results. Similarly the results with respect to information frictions, namely for price impact, order splitting and the imbalance implied by aggregate order flow and the order book, are also in line with our previous findings. Depth at the best level of the order book is a significant driver and implies that discount is smaller when the book is deeper. Again, this is a mechanical effect due to our updated definition: when there is more volume available at the best, the effect of (virtually) walking up the book is smaller, which lowers OTC discount as detailed above.

[Table A.5 about here.]

In Table A.5 we present the results of regressing OTC discount as defined in Equation (B1) on the matched sample described in Section IV.D. A dummy for broker trades in the regression captures the difference in OTC discount between otherwise similar bilateral and broker OTC trades. We find that broker trades feature, on average, $11.1 - 12.7$ percentage points less discount than bilateral interdealer trades, with the difference significant at the 1% level. Despite the altered definition of OTC discount, this result is very much in line with the $14.4 - 15.0$ percentage points difference obtained in Section IV.D and Table V, confirming the robustness of our results to size effects.

[Table A.6 about here.]

Table A.6 shows the results of estimating the drivers of OTC discount with the effects of walking up the book in D2C trades, following the analysis in Section IV.E. As with our main specification, also here the drivers of OTC discount in the D2C segment follow those identified for bilateral interdealer trades. That is, we observe in Table A.6 positive and significant estimation coefficients for trade size and negative significant coefficients for the depth at the MTS best across all specifications and in line with the observations in

Table A.4. We also confirm that D2C trades with dealers with more bargaining power, as captured through their Dealer FE in the matched sample analysis or the dealers' overall trading volume, receive a higher discount. Discounts are also larger when there is an established trading relationship, as proxied with a high dealer-client pair volume, as shown in the main part of our analysis.

Normalizing by Price Levels. Secondly, we take a pricing point of view instead of focusing on transaction costs. Accordingly, we re-define OTC discount (originally defined in Equation (2) in Section III) as

$$OTC\ discount = \frac{\epsilon \left(price^{\text{virtual,MTS}} - price^{\text{observed, OTC}} \right)}{price^{\text{mid,MTS}}}, \tag{B2}$$

where $price^{\text{observed, OTC}}$ is the price of an over-the-counter trade observed in our transaction data and $price^{\text{virtual,MTS}}$ is a virtual price which the same trade would have incurred on MTS at the same time. $price^{\text{mid,MTS}}$ is the MTS mid-price at the time of the trade, and the trade sign ϵ is $+1$ (-1) for buyer- (seller-) initiated trades and inferred by comparing to the contemporaneous MTS mid-price. As the reference price we use the quoted price at the respective best level of the limit order book, i.e. $price^{\text{virtual,MTS}}$ is the best ask (bid) price for buyer- (seller-) initiated trades, thereby disregarding effects of walking up the book. Crucially, the denominator in Equation (B2) 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.7 about here.]

Table A.7 presents summary statistics for OTC discount normalized by 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.8 about here.]

Table A.8 presents the results of regressing OTC discount as defined in Equation (B2) on proxies of market and information frictions as described in Section IV.D and Table IV for our main definition of OTC discount. The estimation results are in line with our previous findings, and since our definition of OTC discount has changed greatly, we abstain from comparing coefficient magnitudes. The effect for very volatile bond-days is still present and significant at the 1% level, while inventory effects are now also present for trades via brokers. As before informedness, as proxied by a higher price impact, order splitting or through aggregate order flow, relates to a lower OTC discount. The impact of price impact and order splitting is especially pronounced for bilaterally negotiated trades, while the aggregate order flow impacts trades via brokers more strongly.

[**Table A.9 about here.**]

Table A.9 presents the results of regressing OTC discount normalized by price on the matched sample described in Section IV.D. The dummy for broker trades indicates that broker trades receive, on average, $0.47 - 0.57$ basis points (of mid-price) less discount than comparable bilateral OTC trades, in line with our previous findings.

[**Table A.10 about here.**]

Table A.10 shows the results of our D2C specifications described in Section IV.E using the OTC discount normalized by price as the dependent variable. Again the estimation results are broadly in line with our main specification, the exception in this case being that the estimation coefficients for order splitting and the depth at the MTS best are no longer significant. The result that a higher dealer bargaining power translates to higher customer OTC discounts remains unchanged, confirming our previous findings.

Appendix C. Additional D2C specifications

Our results for drivers of OTC discount in the D2C segment are robust when considering broader samples.

[Table A.11 about here.]

First, we include in our sample also trades where we are unable to consistently identify the client involved in the trade. Hence, we do not account for customer fixed effects in Table A.11. Specifications (1) and (2) correspond to the respective same specifications in Table VI. Specification (1) shows that for the broader sample and without customer FE we still observe the same factors driving D2C OTC discount, whereas in specification (2) we confirm that clients trading with dealers that have a higher dealer fixed effect in the interdealer market receive a higher OTC discount on average.

[Table A.12 about here.]

Second, we consider D2C trades with a minimum trade size of 100,000 EUR (instead of 2.5 million EUR). The corresponding results are shown in Table A.12. Given the inclusion of smaller trades, the estimation coefficients for logarithmic trade size and volatile days are somewhat smaller, but still highly significant. All other coefficients are very similar to those in our main specifications.

Table A.1. Variable Definitions: Definitions and details for the explanatory and control variables used in the paper. The column variation indicates the dimensions along which the variable varies, where d, t, b, and i indicate day, intraday time (minute), bond, and trade initiator, respectively. n indicates that a variable varies from trade to trade even with all other dimensions equal.

Variable	Description	Source	Variation
OTC discount	See Section III and Equation (2).	transactions, MTS & own calculations	n
Trade size (log)	Logarithm of market value of trade, where market value is in EUR.	transactions	n
Trade size 10-30 million EUR (dummy)	Equals to one if 10 million EUR $\leq$ nominal trade size $\leq$ 30 million EUR.	transactions	n
Trade size $>$ 30 million EUR (dummy)	Equals to one if nominal trade size $>$ 30 million EUR.	transactions	n
Round trade size (dummy)	Equals to one if the nominal value of the trade is 2.5, 5, or 10 million EUR, and zero otherwise.	transactions	n
Inventory	Absolute value of the net imbalance of the initiating trader during the same day in all Bunds up to the moment of the trade, normalized by the average daily volume of trading of the same dealer in all Bunds.	transactions & own calculations	n
Volatility (dummy)	Equals one if intraday volatility for the bond and day is among the top 10 percentile. Intraday volatility is calculated for each bond and day as the square root of the variance of 5-minute returns in MTS mid-prices.	MTS & own calculations	d, b
Dealer volume	Overall trade volume of the dealer. Nominal amount in trillion EUR.	transactions	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
Order splitting (dummy)	Equals one if a dealer trades the same bond more than once on the same trading day and in the same direction.	transactions & own calculations	d, b, i
Aggregate order flow	Imbalance of the aggregate order flow (including dealer and customer trades) in all active bonds in our sample on the same day up to the time of the trade n. Signed for the direction of the trade n and given in billion EUR of nominal amount. E.g. a buy trade in a market situation with overall buying pressure has positive sign.	transactions & own calculations	n
Order book imbalance	Imbalance between volume of limit orders on the best three levels on both sides of the MTS limit order book at the time of trade n. Signed for the direction of the trade n and given in million EUR of nominal amount. E.g. a buy trade happening when there is less depth on the ask than on the bid side has positive sign.	transactions, MTS & own calculations	n

Table A.1 continued on next page.

Table A.1 continued from previous page.

Variable	Description	Source	Variation
Trade via broker (dummy)	Equals one for trades via an interdealer broker and zero otherwise.	transactions	n
MTS half-spread	Half bid-ask spread on MTS in the minute preceding the trade, in basis points.	MTS	d, t, b
Depth at MTS best	Volume available at the best level of the MTS order book on the side of the trade (i.e. ask/bid side for buy/sell) in million EUR.	MTS	d, t, b
Cheapest-to-deliver (dummy)	Equals one if the bond is the cheapest to deliver for its respective futures contract and zero otherwise.	Bloomberg	d, b
2-year Schaetze (dummy)	Equals one if the bond has an original maturity of 2 years (Schaetze) and zero otherwise.	DFA	b
5-year Bobl (dummy)	Equals one if the bond has an original maturity of 5 years (Bobl) and zero otherwise.	DFA	b
30-year Bund (dummy)	Equals one if the bond has an original maturity of 30 years and zero otherwise.	DFA	b
Inv. Mills OTC	Inverse Mills ratio for the choice of trading OTC instead of on exchange. Calculated as $\textit{Inv. Mills OTC}_n = \phi(\gamma'\omega_n)/\Phi(\gamma'\omega_n)$, where ϕ and Φ are the probability and cumulative density functions of the standard normal distribution, and γ is obtained from the estimation of Equation (4) in Table III, specification (1), cf. section IV.C.	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 III, specification (2), cf. section IV.C.	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 III, specification (2), cf. section IV.C.	own calculations	n
Dealer FE (D2D)	Dealer fixed effects estimated in specification (1) of Table IV (cf. section IV.D) for the dealer providing liquidity to the customer in a D2C trade.	own calculations	i
Overall trade volume (dealer)	Overall trade volume of the dealer providing liquidity to the customer in a D2C trade. Nominal amount in trillion EUR. (Cf. variable *Dealer volume*.)	own calculations	i
Overall volume of the dealer-client pair	Overall trade volume of the dealer-customer pair. Nominal amount in billion EUR.	own calculations	i, j

Table A.2. Statistics of Explanatory Variables: Descriptive statistics of explanatory and control variables as defined in Table A.1. The sample consists of interdealer trades for a minimum trade size of 2.5 million EUR for the following samples (as defined in Table I): Panel A refers to all trades on the interdealer exchange MTS in our transactions data, Panel B to bilaterally negotiated interdealer trades and Panel C to interdealer trades via a broker. Panel D refers to the set of customer-initiated dealer-to-customer trades (cf. section II.C), i.e. trades initiated by the customer and where the dealer is a reporting entity to our transactions data. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

Panel A: D2D via MTS

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Trade size (log)	15.78	0.53	14.80	15.45	15.79	16.14	16.46	2,179
Round trade size (dummy)	0.83							2,179
Inventory (%)	0.19	0.22	0.00	0.00	0.10	0.31	0.66	2,179
Volatility (dummy)	0.11							2,176
Price impact (15min, in bp)	1.53	6.28	-3.46	0.00	0.49	1.88	10.91	2,138
Order splitting (dummy)	0.38							2,179
Aggregate order flow (bn EUR)	-0.01	0.48	-0.75	-0.20	-0.00	0.19	0.69	2,179
Order book imbalance (mn EUR)	-1.30	28.66	-32.75	-7.25	-0.00	10.00	25.55	2,179
MTS half-spread (bp)	3.31	5.40	0.25	0.80	1.50	3.00	15.00	2,179
Depth at MTS best (log)	15.96	0.76	14.73	15.42	16.12	16.12	17.50	2,179
Dealer Volume (tn EUR)	0.30	0.30	0.00	0.01	0.11	0.65	0.67	2,179
Issuance day (dummy)	0.05							2,179
Cheapest-to-deliver (dummy)	0.04							2,179
Amount outstanding (log)	23.51	0.37	22.52	23.43	23.56	23.72	23.90	2,179
Bond age (%)	47.82	32.06	1.19	17.47	47.31	79.18	94.18	2,179
Coupon rate (%)	2.24	1.77	0.00	0.50	2.00	3.75	5.00	2,179
End-of-quarter (dummy)	0.05							2,179
End-of-year (dummy)	0.01							2,179
Recent on-the-run (dummy)	0.10							2,179
2-years Schaetze (dummy)	0.21							2,179
5-years Bobl (dummy)	0.22							2,179
30-years Bund (dummy)	0.12							2,179

Table A.2 continued on next page.

Table A.2 continued from previous page.

Panel B: D2D via bilateral OTC

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

Table A.2 continued on next page.

Table A.2 continued from previous page.
Panel C: D2D via broker (D2B)

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

Table A.2 continued on next page.

Table A.2 continued from previous page.

Panel D: D2C customer-initiated (trade size $\geq$ 2.5 million EUR)

Variable	Mean	Std dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	# obs
Trade size (log)	16.21	1.03	14.95	15.44	15.91	17.01	18.21	13,125
Volatility (dummy)	0.12							13,119
Price impact (15min, in bp)	0.37	5.40	-6.90	-0.98	-0.00	1.79	7.72	12,907
Order splitting (dummy)	0.19							13,125
Aggregate order flow (bn EUR)	0.03	0.46	-0.65	-0.15	0.01	0.21	0.76	13,125
Order book imbalance (mn EUR)	1.47	12.88	-20.00	-5.00	-0.00	10.00	20.00	13,125
MTS half-spread (bp)	5.56	7.23	1.11	2.30	3.00	4.50	24.50	13,125
Depth at MTS best (log)	15.83	0.64	14.51	15.42	16.12	16.12	16.81	13,125
Issuance day (dummy)	0.03							13,125
Cheapest-to-deliver (dummy)	0.11							13,125
Amount outstanding (log)	23.54	0.36	22.80	23.50	23.61	23.77	23.90	13,125
Bond age (%)	31.70	29.14	1.12	5.89	21.26	52.98	89.40	13,125
Coupon rate (%)	2.06	1.60	0.00	0.50	1.75	3.25	4.75	13,125
End-of-quarter (dummy)	0.04							13,125
End-of-year (dummy)	0.00							13,125
Recent on-the-run (dummy)	0.21							13,125
2-years Schaetze (dummy)	0.11							13,125
5-years Bobl (dummy)	0.18							13,125
30-years Bund (dummy)	0.11							13,125
Dealer FE (matched)	-3.49	4.75	-12.27	-6.18	-1.26	0.00	0.02	13,125
Overall trade volume (dealer)	0.52	0.19	0.11	0.35	0.65	0.65	0.67	13,125
Overall trade volume of the dealer-client pair	44.33	76.79	0.10	1.97	9.11	33.91	237.54	13,125

Table A.3. Descriptive Statistics of OTC Discount: with walking up the book. *OTC discount*, defined in Equation (B1), 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”), normalized by 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 I, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. The column p-value refers to a t-test of the mean being different from zero and *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,024	40.23	100.28	-96.25	36.00	67.14	85.71	96.67	12.3	0.0000
init. & counterp. ID known	209,427	50.22	66.81	-60.00	40.00	70.00	86.03	96.67	10.1	0.0000
D2D	45,032	47.59	71.37	-76.35	40.00	68.57	85.71	97.00	10.8	0.0000
trade size $\geq$ 2.5 million EUR	20,073	51.65	64.27	-66.67	43.16	71.56	87.50	97.37	10.6	0.0000
D2D via bilateral OTC	6,708	61.64	48.47	-6.37	53.31	74.64	88.00	96.91	5.4	0.0000
D2D via broker (D2B)	13,226	46.59	70.63	-91.42	36.15	69.59	87.18	97.67	13.2	0.0000
D2C	122,963	53.28	63.03	-49.94	44.44	71.70	87.00	96.98	9.2	0.0000
trade size $\geq$ 2.5 million EUR	48,506	51.89	64.02	-57.14	42.86	71.11	86.67	96.90	9.9	0.0000
customer-initiated	13,125	54.06	64.34	-57.84	46.88	74.33	88.57	97.35	9.5	0.0000

Table A.4. 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 (6) and Section IV.D). The dependent variable, *OTC discount*, defined in Equation (B1) in Section V, 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"), normalized by the effective MTS half-spread. v_n, as detailed in Equation (8), is a vector of variables representing market 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 sample consists of bilaterally negotiated OTC trades between dealers in specifications (1) and (2) (row *D2D via bilateral OTC* in Table I) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker (D2B)* in Table I). The minimum trade size is 2.5 million EUR in all specifications. Based on transactions data including all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are obtained through sampling. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Interdealer trading protocol:	bilateral OTC		via broker
	(1)	(2)	(3)
Trade size (log)	1.2736	0.6475	12.2954***
	(1.0088)	(0.8486)	(12.9280)
Inventory	-1.2204**	-1.0520**	0.1793
	(-2.4718)	(-2.3356)	(0.3988)
Volatility (dummy)	-20.8711***	-21.4180***	-18.9284***
	(-6.0236)	(-6.2066)	(-7.1901)
Top 5 dealer (dummy)		7.2903***	
		(6.1131)	
Bottom 5 dealer (dummy)		-33.7447***	
		(-3.6633)	
Price impact (15min, in bp)	-2.0001**	-1.9523**	-0.8182*
	(-2.5680)	(-2.5166)	(-1.7778)
Order splitting (dummy)	-5.1655***	-5.3727***	-3.4159***
	(-4.1154)	(-4.5208)	(-3.6467)
Aggregate order flow (bn EUR)	-0.9774**	-0.9406**	-2.1700***
	(-2.0697)	(-1.9805)	(-5.1031)
Order book imbalance (mn EUR)	0.2630	0.3003	0.9442**
	(0.4267)	(0.4960)	(2.0561)
MTS half-spread (bp)	12.4325***	12.3287***	10.4576***
	(10.2000)	(10.4752)	(12.5038)
Depth at MTS best (log)	-2.2606***	-2.4764***	-3.5957***
	(-4.0783)	(-4.5395)	(-7.3049)
Inv. Mills OTC	-2.1265***	-2.0190***	0.5920
	(-3.1034)	(-2.9568)	(0.8390)
Inv. Mills Bilateral	-0.9775	-1.5309	
	(-0.5151)	(-1.4013)	
Inv. Mills Broker			-1.7527
			(-1.2340)
Intercept	67.7257***	66.9038***	50.0639***
	(60.1578)	(68.3068)	(77.1601)
R^2	0.1071	0.0966	0.2383
R^2_{adjusted}	0.0846	0.0781	0.2299
R^2_{within}	0.0482	0.0570	0.0979
N	6,578	6,578	12,947
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Table A.5. 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 (9) and Section IV.D). The dependent variable, *OTC discount*, defined in Equation (B1) in Section V, 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"), normalized by the effective MTS half-spread. v_n, as detailed in Equation (10), 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 market and information frictions, as well as control variables, including fixed effects for bond and initiating dealer respectively. 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 IV.D. The minimum trade size is 2.5 million EUR in all specifications.

	(1)	(2)
Trade via broker (dummy)	-11.1037***	-12.6575***
	(-6.0450)	(-6.0888)
Trade size (log)		9.3527***
		(8.3839)
Inventory		-0.1489
		(-0.2059)
Volatility (dummy)		-6.0771
		(-1.3302)
Price impact (15min, in bp)		0.5280
		(0.6418)
Order splitting (dummy)		-2.0453
		(-1.7268)
Aggregate order flow (bn EUR)		-1.3598*
		(-2.0208)
Order book imbalance (mn EUR)		-0.4626
		(-1.1302)
MTS half-spread (bp)		6.4864***
		(4.1658)
Depth at MTS best (log)		-3.2923***
		(-5.2349)
R^2	0.0872	0.1640
R^2_{adjusted}	0.0619	0.1377
R^2_{within}	0.0257	0.1077
N	4,194	4,194
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table A.6. OTC Discount in the D2C segment: with walking up the book. OLS Estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ on dealer-to-customer trades (cf. Equation (12) and Section IV.E). The dependent variable, *OTC discount*, defined in Equation (B1) in Section V, 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"), normalized by the effective MTS half-spread. v_n, as detailed in Equation (13), is a vector of trade and bond characteristics proxying for market and information frictions, dealer-client characteristics, and containing control variables, including fixed effects for bond and initiating customer respectively. The sample consists of bilateral OTC trades between dealers and customers, where the dealer is a reporting entity to our transactions data and the trade was initiated by the customer (row *D2C – customer-initiated* in Table I). The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, customer, and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)	(5)
Trade size (log)	5.8240***	5.8160***	5.8939***	5.6671***	5.6592***
	(8.6565)	(8.6542)	(8.8291)	(8.5454)	(8.5285)
Volatility (dummy)	-9.4645***	-9.3851***	-9.3520***	-9.4532***	-9.3738***
	(-5.3971)	(-5.4148)	(-5.3319)	(-5.4312)	(-5.4470)
Price impact (15min, in bp)	-0.9480*	-0.9323*	-0.9432*	-0.9485*	-0.9328*
	(-1.6961)	(-1.6701)	(-1.6913)	(-1.6890)	(-1.6629)
Order splitting (dummy)	-3.3758***	-3.4115***	-3.5352***	-3.3706***	-3.4063***
	(-2.6882)	(-2.7309)	(-2.8402)	(-2.6668)	(-2.7082)
Aggregate order flow (bn EUR)	-0.8952*	-0.8953*	-0.8900*	-0.8839*	-0.8840*
	(-1.9403)	(-1.9506)	(-1.9360)	(-1.9170)	(-1.9269)
Order book imbalance (mn EUR)	-0.0314	-0.0309	-0.0334	-0.0307	-0.0303
	(-1.1272)	(-1.1054)	(-1.2086)	(-1.1015)	(-1.0800)
MTS half-spread (bp)	7.2484***	7.2754***	7.3960***	7.2744***	7.3013***
	(4.9068)	(4.9138)	(4.9947)	(4.9454)	(4.9537)
Depth at MTS best (log)	-1.8801***	-1.8632***	-1.8521***	-1.8812***	-1.8644***
	(-4.1176)	(-4.0758)	(-4.0770)	(-4.1494)	(-4.1092)
Dealer FE (D2D)		2.3775***			2.3758***
		(3.7938)			(3.8552)
Overall trade volume (dealer)			2.5635***		
			(3.6971)		
Overall volume of the dealer-client pair				10.1595***	10.1543***
				(3.1906)	(3.2699)
R^2	0.3284	0.3292	0.3295	0.3294	0.3302
R^2_{adjusted}	0.3008	0.3015	0.3018	0.3018	0.3026
R^2_{within}	0.0232	0.0244	0.0247	0.0247	0.0259
N	12,710	12,710	12,710	12,710	12,710
Bond FE	yes	yes	yes	yes	yes
Customer FE	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes

Table A.7. Descriptive Statistics of OTC Discount: normalized by price. *OTC discount*, defined in Equation (B2), 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, normalized by 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 I, excluding interdealer trades via MTS, for which OTC discount is, by definition, equal to zero. The column p-value refers to a t-test of the mean being different from zero and *share* < 0 gives the share of trades with an OTC premium (negative OTC discount) in percent. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017.

		OTC discount (%)								
	# obs	Mean	Std Dev	5 Pcl	25 Pcl	Median	75 Pcl	95 Pcl	share < 0 (%)	p-value (%)
full sample	443,033	2.92	6.82	-3.09	0.78	1.88	3.36	15.55	13.5	0.0000
init. & counterp. ID known	209,427	2.94	5.15	-2.00	0.90	1.95	3.36	14.55	11.3	0.0000
D2D	45,032	2.16	4.49	-2.83	0.71	1.71	2.82	11.49	13.2	0.0000
trade size $\geq$ 2.5 million EUR	20,073	1.77	4.29	-3.35	0.50	1.45	2.61	9.48	15.8	0.0000
D2D via bilateral OTC	6,708	2.10	3.26	-0.58	0.98	1.80	2.82	5.84	6.9	0.0000
D2D via broker (D2B)	13,226	1.59	4.70	-4.39	0.17	1.20	2.42	11.02	20.4	0.0000
D2C	122,963	3.12	5.21	-1.70	0.98	2.03	3.44	15.05	10.1	0.0000
trade size $\geq$ 2.5 million EUR	48,506	2.33	4.40	-2.03	0.76	1.76	2.92	11.52	12.4	0.0000
customer-initiated	13,125	2.51	4.87	-2.06	0.80	1.81	3.02	13.11	12.1	0.0000

Table A.8. Intermediation Frictions and OTC Discount: normalized by price. 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 (6) and Section IV.D). The dependent variable, *OTC discount*, defined in Equation (B2) in Section V, 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, normalized by the quoted mid-price on MTS. v_n, as detailed in Equation (8), is a vector of variables representing market 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 sample consists of bilaterally negotiated OTC trades between dealers in specifications (1) and (2) (row *D2D via bilateral OTC* in Table I) and interdealer trades via interdealer brokers in specification (3) (row *D2D via broker (D2B)* in Table I). The minimum trade size is 2.5 million EUR in all specifications. Based on transactions data including all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are obtained through sampling. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

Interdealer trading protocol:	bilateral OTC		via broker
	(1)	(2)	(3)
Trade size (log)	-0.5237***	-0.5845***	-0.1630*
	(-3.8927)	(-6.9078)	(-1.8797)
Inventory	-0.0834**	-0.0925***	-0.0814**
	(-2.0457)	(-2.6287)	(-2.0434)
Volatility (dummy)	-2.5125***	-2.5462***	-2.6625***
	(-4.6436)	(-4.7483)	(-8.1268)
Top 5 dealer (dummy)		0.4643***	
		(5.6667)	
Bottom 5 dealer (dummy)		-2.5713**	
		(-2.0261)	
Price impact (15min, in bp)	-0.2597**	-0.2576**	-0.0768
	(-2.3183)	(-2.3024)	(-1.0371)
Order splitting (dummy)	-0.3023***	-0.3667***	-0.1952**
	(-3.2224)	(-4.1083)	(-2.4077)
Aggregate order flow (bn EUR)	0.0177	0.0204	-0.0986***
	(0.4881)	(0.5395)	(-2.8939)
Order book imbalance (mn EUR)	0.0398	0.0461	0.0211
	(1.1891)	(1.3950)	(0.7682)
MTS half-spread (bp)	4.4317***	4.4446***	3.9868***
	(23.3742)	(23.4349)	(25.3838)
Depth at MTS best (log)	0.0403	0.0310	-0.0061
	(0.8958)	(0.7233)	(-0.1611)
Inv. Mills OTC	0.0167	0.0371	0.0586
	(0.3300)	(0.7457)	(1.0135)
Inv. Mills Bilateral	-0.0335	-0.1061	
	(-0.1720)	(-1.0066)	
Inv. Mills Broker			-0.3671***
			(-3.2047)
Intercept	2.2803***	2.1654***	1.5989***
	(22.5399)	(22.9548)	(29.5257)
R^2	0.4763	0.4717	0.4281
R^2_{adjusted}	0.4630	0.4609	0.4218
R^2_{within}	0.2595	0.2643	0.1972
N	6,578	6,578	12,947
Bond FE	yes	yes	yes
Dealer FE	yes	no	yes
Controls	yes	yes	yes

Table A.9. Differences in OTC Discount across Interdealer Protocols: normalized by price. OLS Estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ (cf. Equation (9) and Section IV.D). The dependent variable, *OTC discount*, defined in Equation (B2) in Section V, 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, normalized by the quoted mid-price on MTS. v_n, as detailed in Equation (10), 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 market and information frictions, as well as control variables, including fixed effects for bond and initiating dealer respectively. 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 IV.D. The minimum trade size is 2.5 million EUR in all specifications.

	(1)	(2)
Trade via broker (dummy)	-0.5698***	-0.4679***
	(-7.5583)	(-4.7272)
Trade size (log)		-0.0153
		(-0.2221)
Inventory		0.0121
		(0.5282)
Volatility (dummy)		-0.3608
		(-1.4712)
Price impact (15min, in bp)		0.1301**
		(2.6423)
Order splitting (dummy)		-0.1115*
		(-2.1138)
Aggregate order flow (bn EUR)		-0.0570
		(-1.5844)
Order book imbalance (mn EUR)		-0.0379**
		(-2.7832)
MTS half-spread (bp)		2.9508***
		(16.3520)
Depth at MTS best (log)		-0.0094
		(-0.4404)
R^2	0.4223	0.6693
R^2_{adjusted}	0.4063	0.6589
R^2_{within}	0.0160	0.4367
N	4,194	4,194
Bond FE	yes	yes
Dealer FE	yes	yes
Controls	no	yes

Table A.10. OTC Discount in the D2C segment: normalized by price. OLS Estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ on dealer-to-customer trades (cf. Equation (12) and Section IV.E). The dependent variable, *OTC discount*, defined in Equation (B2) in Section V, 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, normalized by the quoted mid-price on MTS. v_n, as detailed in Equation (13), is a vector of trade and bond characteristics proxying for market and information frictions, dealer-client characteristics, and containing control variables, including fixed effects for bond and initiating customer respectively. The sample consists of bilateral OTC trades between dealers and customers, where the dealer is a reporting entity to our transactions data and the trade was initiated by the customer (row *D2C – customer-initiated* in Table I). The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, customer, and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)	(5)
Trade size (log)	-0.3009***	-0.3015***	-0.2941***	-0.3154***	-0.3160***
	(-3.4657)	(-3.4813)	(-3.4533)	(-3.6158)	(-3.6299)
Volatility (dummy)	-1.1638***	-1.1579***	-1.1529***	-1.1627***	-1.1569***
	(-4.9219)	(-4.9275)	(-4.8927)	(-4.9169)	(-4.9224)
Price impact (15min, in bp)	-0.0207	-0.0196	-0.0203	-0.0208	-0.0196
	(-0.1586)	(-0.1498)	(-0.1552)	(-0.1586)	(-0.1499)
Order splitting (dummy)	-0.1974	-0.2000	-0.2128*	-0.1969	-0.1996
	(-1.6292)	(-1.6515)	(-1.7528)	(-1.6178)	(-1.6397)
Aggregate order flow (bn EUR)	-0.1461***	-0.1461***	-0.1456***	-0.1450***	-0.1450***
	(-3.0374)	(-3.0415)	(-3.0370)	(-3.0209)	(-3.0250)
Order book imbalance (mn EUR)	-0.0001	-0.0001	-0.0003	-0.0000	-0.0000
	(-0.0510)	(-0.0338)	(-0.1497)	(-0.0215)	(-0.0046)
MTS half-spread (bp)	4.0788***	4.0808***	4.0930***	4.0812***	4.0832***
	(23.1950)	(23.2289)	(23.4569)	(23.2721)	(23.3070)
Depth at MTS best (log)	0.0202	0.0215	0.0229	0.0201	0.0214
	(0.4311)	(0.4571)	(0.4937)	(0.4293)	(0.4552)
Dealer FE (D2D)		0.1756***			0.1755***
		(3.1690)			(3.1958)
Overall trade volume (dealer)			0.2475***		
			(4.0176)		
Overall volume of the dealer-client pair				0.9429**	0.9425**
				(2.3423)	(2.3620)
R^2	0.5938	0.5942	0.5946	0.5946	0.5949
R^2_{adjusted}	0.5771	0.5775	0.5779	0.5778	0.5782
R^2_{within}	0.2326	0.2332	0.2341	0.2339	0.2346
N	12,710	12,710	12,710	12,710	12,710
Bond FE	yes	yes	yes	yes	yes
Customer FE	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes

Table A.11. OTC Discount in the D2C segment: including unidentified customers. OLS Estimation of $\mathit{OTC\ discount}_n = \gamma' v_n + \varepsilon_n$ on dealer-to-customer trades (cf. Equation (12) and Section IV.E). The dependent variable, *OTC discount*, defined in Equation (2) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, normalized by the MTS half-spread. v_n, as detailed in Equation (13), is a vector of trade and bond characteristics proxying for market and information frictions, dealer-client characteristics, and containing control variables, including fixed effects for bond and initiating customer respectively. 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. Differently from our main D2C specifications, the sample here contains also trades where the customer can not be identified (tracked) across trades, allowing for a broader sample (cf. Section C in the Appendix). We consequently do not include customer fixed effects. The minimum trade size is 2.5 million EUR in all specifications. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, customer, and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

	(1)	(2)
Trade size (log)	-2.7327***	-3.2045***
	(-3.7651)	(-4.2416)
Volatility (dummy)	-12.6756***	-12.4724***
	(-7.1181)	(-6.9700)
Price impact (15min, in bp)	-0.5238	-0.5402
	(-1.3626)	(-1.4294)
Order splitting (dummy)	-2.2542**	-2.5315***
	(-2.5559)	(-2.9645)
Aggregate order flow (bn EUR)	-1.0060**	-1.0452**
	(-2.4509)	(-2.5603)
Order book imbalance (mn EUR)	0.0316	0.0266
	(1.4178)	(1.1806)
MTS half-spread (bp)	14.2379***	14.0743***
	(7.1533)	(7.1371)
Depth at MTS best (log)	1.7455***	1.7217***
	(3.8918)	(3.8774)
Dealer FE (D2D)		3.0813***
		(4.5343)
R^2	0.0760	0.0793
R^2_{adjusted}	0.0722	0.0755
R^2_{within}	0.0341	0.0376
N	31,424	31,424
Bond FE	yes	yes
Customer FE	no	no
Controls	yes	yes

Table A.12. OTC Discount in the D2C segment: including medium-sized trades. OLS Estimation of $OTC\ discount_n = \gamma' v_n + \varepsilon_n$ on dealer-to-customer trades (cf. Equation (12) and Section IV.E). The dependent variable, *OTC discount*, defined in Equation (2) in Section III, is the difference between the observed price of an OTC trade and the price a similar trade would have incurred on MTS, normalized by the MTS half-spread. v_n, as detailed in Equation (13), is a vector of trade and bond characteristics proxying for market and information frictions, dealer-client characteristics, and containing control variables, including fixed effects for bond and initiating customer respectively. 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. The minimum trade size is 100,000 EUR in all specifications. Based on regulatory data of all transactions in German Bunds involving German financial institutions from June 2011 through December 2017. Standard errors are clustered at bond, customer, and daily time level. t-values are given in brackets and *, ** and *** denote significance at the 10%, 5% and 1% level respectively.

	(1)	(2)	(3)	(4)	(5)
Trade size (log)	-3.4795***	-3.4966***	-3.4259***	-3.5426***	-3.5576***
	(-5.1946)	(-5.2330)	(-5.1367)	(-5.2990)	(-5.3360)
Volatility (dummy)	-9.1045***	-9.1336***	-9.1216***	-9.0940***	-9.1224***
	(-6.1166)	(-6.1852)	(-6.1301)	(-6.1303)	(-6.1973)
Price impact (15min, in bp)	-1.1580***	-1.1524***	-1.1559***	-1.1595***	-1.1541***
	(-2.7450)	(-2.7437)	(-2.7455)	(-2.7421)	(-2.7408)
Order splitting (dummy)	-3.7905***	-3.8324***	-3.9069***	-3.7583***	-3.7995***
	(-2.8023)	(-2.8367)	(-2.8933)	(-2.7706)	(-2.8040)
Aggregate order flow (bn EUR)	-0.7908**	-0.7881**	-0.7799**	-0.7700**	-0.7679**
	(-2.0831)	(-2.0748)	(-2.0521)	(-2.0307)	(-2.0234)
Order book imbalance (mn EUR)	-0.0060	-0.0060	-0.0069	-0.0061	-0.0061
	(-0.2574)	(-0.2553)	(-0.2946)	(-0.2594)	(-0.2573)
MTS half-spread (bp)	12.0323***	12.0646***	12.1212***	12.0235***	12.0549***
	(6.8606)	(6.8523)	(6.8823)	(6.8749)	(6.8674)
Depth at MTS best (log)	2.0058***	2.0349***	2.0362***	2.0101***	2.0380***
	(5.8075)	(5.8450)	(5.8826)	(5.8139)	(5.8528)
Dealer FE (D2D)		2.1253***			2.0537***
		(3.5005)			(3.4439)
Overall trade volume (dealer)			2.0293***		
			(3.2008)		
Overall volume of the dealer-client pair				12.3656***	12.0837***
				(3.3554)	(3.3778)
R^2	0.3462	0.3467	0.3467	0.3469	0.3474
R^2_{adjusted}	0.3280	0.3285	0.3285	0.3287	0.3292
R^2_{within}	0.0279	0.0287	0.0287	0.0290	0.0297
N	25,984	25,984	25,984	25,984	25,984
Bond FE	yes	yes	yes	yes	yes
Customer FE	yes	yes	yes	yes	yes
Controls	yes	yes	yes	yes	yes

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