Market Structure and Transaction Costs of Index CDSs*

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Abstract

Using transaction data, we study the two-tiered structure of the index CDS market after the implementation of the Dodd-Frank Act. We identify dealer-to-client (D2C) trades and interdealer (D2D) trades. Average transaction costs are higher for D2C trades, reflecting higher average price impact. D2C trades Granger-cause D2D trades consistent with the interdealer market being used for managing inventory risk. Unique order-book data show that D2D transaction costs and price impacts vary across trading protocols, with mid-market matching and workup attracting liquidity-motivated trades. D2C prices are typically better than those available on the main interdealer limit order book, which may explain the endurance of the two-tiered market structure.

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1 Introduction

The index credit default swap (CDS) market constitutes an important component of the corporate credit market. Index CDSs allow banks, asset managers, and other institutional investors to efficiently hedge and trade aggregate credit risk in the economy. Unlike single-name CDSs, index CDSs have remained popular since the financial crisis with tens of billion dollars of notional amount traded on a daily basis. Nevertheless, little is known about the cost of trading in this important market.

The index CDS market is also interesting as a test case of how new regulation introduced in the wake of the financial crisis affects the structure of swap markets. Since its inception in 2003, the index CDS market has operated as a classic two-tiered over-the-counter (OTC) market in which global derivatives dealers provide liquidity to clients in the dealer-to-client (D2C) segment of the market, and dealers trade among themselves in the interdealer (D2D) segment of the market. New swap market regulation following the Dodd-Frank Act had the potential to change this market structure by mandating trades in the most liquid index CDSs to be executed on so-called swap execution facilities (SEFs).[1] These regulated trading platforms are required to offer trading in order books, which opens up the market to all-to-all trading where clients can compete with dealers for liquidity provision. However, SEFs can also offer trading via request for quote (RFQ), which mimics traditional trading in OTC markets. Several years after the new regulation was fully implemented, all-to-all trading has yet to materialize. Instead, the two-tiered market structure persists, with D2C trades taking place on one group of SEFs (almost exclusively via name-disclosed RFQs) and D2D trades taking place on another group of SEFs (using a diverse set of anonymous trading protocols) run by interdealer brokers (IDBs).[2]

[1] Other key elements of the new swap market regulation are post-trade transparency via the immediate dissemination of trades and central clearing of index CDSs with standardized contract terms.

[2] Referring to both the index CDS and the interest rate swap markets, a recent article summarized the current situation as "...dealer banks still trade together privately in one segment of the market and the buy side

The endurance of this bifurcated market structure could suggest that this is indeed the optimal structure of a market in which trades occur relatively infrequently and in very large sizes; see, e.g., Giancarlo (2015).[3] On the other hand, some market participants have accused dealers of resisting a transition to an all-to-all market structure in order to limit competition from non-dealer liquidity providers; see, e.g., Managed Funds Association (2015).

Motivated by these issues, the paper has three related objectives. First, we characterize the two-tiered structure of the post-Dodd-Frank index CDS market. Second, we analyze transaction costs and price impacts across market segments and trading protocols. Third, we estimate dealer profits from liquidity provision.

We use transaction data from October 2, 2013 (the date on which the first SEFs started operating) to October 16, 2015, and we focus on the two most popular credit indices, CDX.IG and CDX.HY, which cover the investment-grade and high-yield components, respectively, of the North American corporate credit market. The transaction data include execution timestamps, transaction prices, and trade sizes up to certain notional caps. In addition, we develop algorithms that allow us to identify, for each trade, the SEF on which the trade took place and the type of trade (outright trade, index roll, curve trade, or delta hedge of an index swaption or tranche swap). The SEF on which the trade took place in turn reveals whether the trade is D2C or D2D.[4]

Trading volumes are large. The average daily notional amounts traded in the D2C segment are USD 9.843 billion and USD 3.705 billion for CDX.IG and CDX.HY, respectively. In the D2D segment, the corresponding numbers are USD 1.354 billion and USD 0.402 billion. Outright trades account for the majority of trading volume. Index rolls constitute the

still executes via RFQ to the dealers in another. Proponents of this view say that nothing really changed in terms of how firms execute swaps except that the buy side has gone from RFQ-ing one dealer to RFQ-ing three. This appears to be in stark contrast to the all-to-all trading model envisioned for the swaps markets by regulators under Dodd-Frank." See "SEFs: A Market Divided," *Profit & Loss*, October 22, 2015.

[3]For example, for CDX.IG, one of the two most actively traded credit indices, there are often not more than 100 trades per day, and trade sizes frequently exceed USD 100 million.

[4]Because we identify D2C and D2D trades based on the SEF on which the trade took place, our sample is limited to the period during which SEFs were in operation and to trades executed on SEFs.

second most important type of trade. Among outright trades, trading activity concentrates in five-year CDSs on the most recently issued (on-the-run) index. Among index rolls, trading activity concentrates in rolls between five-year CDSs on the on-the-run index and five-year CDSs on the previous on-the-run (immediate off-the-run) index. These trade types are the focus of the paper.

We measure transaction cost by the effective half-spread, which is the difference between the transaction price and the contemporaneous value of Markit's intraday mid-quote (both expressed in terms of par spreads). We measure price impact as the change in the mid-quote over a period of approximately 15 minutes following a trade. In case of outright trades, transaction costs of D2C trades are consistently higher than those of D2D trades. For CDX.IG, average transaction costs are 0.137 basis points (bps) and 0.088 bps for D2C and D2D trades, respectively, with the difference of 0.049 bps being statistically significant. The corresponding numbers for CDX.HY are 0.674 bps and 0.402 bps, respectively, with the difference of 0.273 bps again being statistically significant. These transaction cost differentials are largely due to D2C trades having higher price impact than D2D trades. For CDX.IG, average price impact is 0.043 bps higher for D2C trades, and for CDX.HY average price impact is 0.262 bps higher for D2C trades. The higher price impact of D2C trades likely reflects the institutional nature of the index CDS market in which clients are professional investors who may have private information about the credit risk of certain index constituents (see, e.g., Acharya and Johnson (2007) and Ivashina and Sun (2011)) or may have an advantage over dealers in interpreting public information in relation to the aggregate credit risk in the economy.[5] In contrast, D2D trades mainly serve to manage dealers' inventory risk (see, e.g., Reiss and Werner (1998)). After taking price impact into account, there is no significant difference in transaction costs of D2C and D2D trades.

[5] In support of superior information processing by institutional investors, Hendershott, Livdan, and Schürhoff (2015) show that institutional order flow predicts the occurrence and sentiment of news as well as news-announcement-day equity market returns.

In contrast to outright trades, index rolls are not informationally motivated but rather motivated by investors seeking to maintain a liquid credit exposure with a relatively constant maturity profile. Consistent with this, we find that transaction costs and price impacts of index rolls are both smaller than those of outright trades and similar across D2C and D2D index rolls.

We also investigate how trade characteristics and market conditions affect transaction costs and price impacts. Transaction costs and price impacts increase with trade size, Markit's intraday bid-ask spread, and volatility implied by index swaptions; i.e., options on index CDSs. Our findings regarding differences in transaction costs and price impacts of D2C and D2D trades are robust to controlling for these determinants in trade-by-trade regressions. Moreover, our findings also prevail in subsamples of pairs of D2C and D2D trades with matching trade characteristics that are executed at around the same time.

In addition, we analyze the dynamics of D2C trades, D2D trades, and quotes using a vector autoregressive (VAR) model in the spirit of Hasbrouck (1991a, 1991b). Order flow is persistent and D2C trades Granger-cause D2D trades, which is consistent with inventory management taking place in the interdealer market. In line with our findings based on the above-mentioned 15-minute price impact measure, D2C trades have larger contemporaneous and cumulative effects on quotes than D2D trades.

While virtually all D2C trades are executed via RFQs, a number of different trading protocols are used in the interdealer market. We refine the characterization of the interdealer market by investigating how transaction costs and price impacts vary across trading protocols. To this end, we exploit unique order-book data from the main IDB SEF, the GFI Swaps Exchange. In addition to a standard limit order book, this SEF offers two trading protocols—mid-market matching and workup—that facilitate trade by means of size discovery; i.e., by means of quantity exchange at a fixed price (see, e.g., Duffie and Zhu (2015)).[6] In contrast

[6]The two trading protocols differ in how the price is fixed, for how long quantity can be exchanged, and what

to standard market orders, execution of orders for matching and workup is uncertain.

Mid-market matching is the dominant trading protocol and accounts for 52.2% and 58.6%, respectively, of the trading volume in five-year on-the-run CDX.IG and CDX.HY. Workup is also frequently used and accounts for 19.9% and 15.6%, respectively. Mid-market matches have significantly lower average transaction costs and price impact than trades in the limit order book. This is consistent with Zhu's (2014) venue-selection model, in which liquidity traders prefer a mid-point dark pool (roughly equivalent to mid-market matching) that offers price improvement but does not guarantee execution, while informed traders prefer the certainty of executing against limit orders. By design, a workup is initiated by a trade in the limit order book and occurs at the same price. However, the average price impact of workups is close to zero implying that this trading protocol allows for increasing the size of a limit-order-book trade at little additional price impact. These results show that average transaction costs and price impact of D2D trades mask significant heterogeneity across trading protocols, with size-discovery protocols attracting liquidity-motivated trades.

Finally, we use the GFI data to estimate dealer profits from liquidity provision in five-year on-the-run index CDSs. Assuming that dealers immediately close D2C trades by mid-market matches, estimated profits are USD 0.433 million and USD 0.808 million per day for CDX.IG and CDX.HY, respectively. However, assuming instead that dealers immediately close positions at the best bid or offer on the limit order book, estimated profits are negative. Because of the execution risk associated with mid-market matching, this suggests that dealers only make profits through their willingness to bear inventory risk.

From the perspective of clients who value immediacy, our results show that the current market structure delivers very low transaction costs. The prices that clients obtain via name-

information about unfilled interests is displayed to market participants. In case of continuous mid-market matching, the price is fixed by a broker, quantity can be exchanged until the next time the broker resets the price, and market participants are informed when there is interest for matching without being informed about the direction and size of interests. In case of workup, the price is fixed by an initiating limit-order-book-trade, quantity can be exchanged for a short period of time following the initiating trade, and market participants are informed about the direction and size of interests.

disclosed RFQs are typically better than those available on the limit order book of the main IDB SEF. Indeed, 96.0% and 96.6% of D2C trades in CDX.IG and CDX.HY, respectively, are executed at prices that are strictly more favorable than the contemporaneous best bid or offer on the limit order book of the GFI Swaps Exchange. This suggests that the two-tiered market structure—at least when combined with measures limiting dealer market power, such as post-trade transparency and a requirement to put a minimum number of dealers in competition for trades—constitutes a viable alternative to all-to-all trading in swap markets.[7]

1.1 Related Literature

The paper relates to a number of recent studies of how various provisions of the Dodd-Frank Act affect swap market liquidity. Loon and Zhong (2016) show that post-trade transparency and central clearing have a positive impact on liquidity in the index CDS market. Benos, Payne, and Vasios (2016) show that pre-trade transparency (the mandate to trade on SEFs) has a positive impact on liquidity in the interest rate swap market. In contrast, we focus on the structure of the index CDS market after the full implementation of the new swap market regulation and analyze transaction costs across the two segments of the market. Moreover, we contribute to the literature by showing how various features of swap trading, such as the packaging of trades, mid-market matching, and workup, affect the cost at which a swap can be transacted.

The paper also relates to studies of transaction costs in the related markets for single-name CDSs and corporate bonds, both of which function as traditional OTC markets with relatively high search costs. For single-name CDSs, Biswas, Nikolova, and Stahel (2015) report average effective half-spreads in upfront terms of 14 bps for D2C trades in typical

[7]Proponents of bringing all market participants onto one limit order book typically argue that it would (i) increase quote competition among dealers and (ii) allow clients to occasionally supply liquidity via limit orders thereby lowering overall transaction costs (although at the cost of execution risk). However, a limit order book arguably works best when trading is continuous and it is not necessarily optimal when trading is more episodic as is the case for index CDSs.

sizes of approximately USD 5 million. For a recent sample of corporate bonds, Harris (2015) reports average relative effective half-spreads in price terms of 39 bps for institutional-sized D2C trades.[8] For comparison, for D2C trades in CDX.IG and CDX.HY, average effective half-spreads in upfront terms are 0.66 bps and 3.03 bps, respectively, and average relative effective half-spreads in price terms are 0.65 bps and 2.86 bps, respectively. As such, transaction costs of index CDSs are about an order of magnitude lower than those of single-name CDSs and corporate bonds. Also, in contrast to virtually all corporate bond studies, but consistent with standard models of asymmetric information and inventory control, we find that transaction costs increase with trade size.

Finally, the paper relates to empirical studies of size-discovery trading protocols. Size discovery is widely used in the equity market (in the form of mid-point dark pools) and in the Treasury market (in the form of workup). In both markets, the trades that occur through size discovery tend to be less informed; see, e.g., Comerton-Forde and Putniņš (2015) and Fleming and Nguyen (2015). We provide the first analysis of size discovery in swap markets. In addition, we study a trading platform that offers two size-discovery protocols—mid-market matching and workup—providing insights into the relative importance and different impacts of the two trading protocols.

Theoretically, a number of papers show how a two-tiered market structure can arise endogenously (see, e.g., Atkeson, Eisfeldt, and Weill (2013), Babus and Parlatore (2016), and Wang (2016)). Dunne, Hau, and Moore (2015) model price formation in a two-tiered market structure but take the structure as given.

The paper is organized as follows: Section 2 describes the structure of the index CDS market and the regulatory reforms set forth by the Dodd-Frank Act. Section 3 discusses the data and the identification algorithms. Section 4 compares D2C and D2D transaction costs

[8]We benchmark against Harris (2015) because his sample period overlaps with ours and his method of computing transaction costs is similar to ours. Earlier studies using different methodologies also report large transaction costs of corporate bonds; see, e.g., Edwards, Harris, and Piwowar (2007), Goldstein, Hotchkiss, and Sirri (2007), and Hendershott and Madhavan (2015).

and investigates how transaction costs vary with trade characteristics and market conditions. Section 5 analyzes the dynamics of trades and quotes using VAR methods. Section 6 uses GFI data to investigate D2D transaction costs across different trading protocols and to estimate dealer profits from liquidity provision. Section 7 concludes, and data-related details and robustness checks are contained in an Internet Appendix.

2 The Index CDS Market

This section briefly describes index CDSs and the structure of the market in which these contracts trade. Furthermore, it discusses regulatory reforms set forth by the Dodd-Frank Act.

2.1 Index Credit Default Swaps

An index CDS is a standardized credit derivative contract on a diversified index of obligors. Over the life of the contract, the credit protection seller provides default protection on each index constituent and, in return, receives periodic premium payments according to the fixed spread of the contract. At initiation, counterparties exchange an upfront amount equal to the present value of the contract. However, when quoting a contract, market participants either use the "par spread" or the "price." The par spread is the fixed spread that makes the upfront amount equal to zero and the price is one minus the upfront amount per dollar of notional.[9] We use par spreads throughout. Typically, contract tenors between one and ten years can be traded but the five-year contract tenor is the most liquid.

Twice a year, on the so-called index roll dates in March and September, a new index—or, more precisely, a new series of an index—is launched, with obligors being revised according

[9] The two ways of quoting contracts are equivalent under the market convention of using the ISDA CDS Standard Model to convert par spreads to prices, and vice versa.

to credit rating and liquidity criteria.[10] Obligors that fail to maintain a credit rating within a specified range, due to either up- or downgrades, and obligors whose single-name CDSs have deteriorated significantly in terms of their trading activity are replaced by the most actively traded obligors meeting the credit rating requirements. Typically, liquidity is concentrated in the most recently launched index, which is referred to as the on-the-run index. All previously launched indices are referred to as off-the-run indices.

The administrator of the most popular credit indices is Markit, and its benchmark credit indices of investment-grade and high-yield credit risk in North America are CDX.IG and CDX.HY, respectively. The former comprises 125 North American obligors with investment-grade credit ratings, and the latter comprises 100 North American obligors with non-investment-grade credit ratings. These indices are the focus of the paper.

2.2 Pre-Dodd-Frank Market Structure

Index CDSs used to be traded in a relatively opaque two-tiered OTC market. In the D2C segment of the market, dealers provided liquidity to their institutional clients. D2C trades were either negotiated over the phone or executed electronically on trading platforms, such as MarketAxess or Tradeweb.[11] Electronic trade execution was typically via name-disclosed RFQs that enable querying multiple dealers simultaneously for an executable one-sided market of a given notional amount.

In the D2D segment of the market, dealers traded with each other typically involving IDB intermediation. D2D trades were either voice brokered or executed electronically on an IDB's order book. IDB intermediation guaranteed that trades were executed anonymously and that access to the interdealer market was restricted to dealers.

[10] An index's series number uniquely determines the obligors in the index.

[11] Electronic trading platforms for index CDSs emerged in 2005 (see "MarketAxess launches CDS index trading platform," *Risk Magazine*, September 12, 2005, and "TradeWeb Launches its Global Online Market for Credit Derivatives: TradeWeb CDS," *Press Release*, October 26, 2005), but their share of trading volume is unknown.

2.3 The Dodd-Frank Act and Current Market Structure

The Dodd-Frank Act tasked the Commodity Futures Trading Commission (CFTC) with regulating the index CDS market in order to promote financial stability as well as post- and pre-trade transparency. Pursuing these objectives, the CFTC enacted a clearing requirement for index CDSs with standardized contract terms, a reporting requirement, and a trade execution requirement.[12]

The reporting requirement mandates real-time trade reporting of all index CDS trades to so-called swap data repositories (SDRs). SDRs publicly disseminate the received transaction data; dissemination is immediate unless the trade qualifies as a block in which case dissemination is delayed by at least 15 minutes.[13]

The trade execution requirement mandates that the most liquid index CDSs trade on SEFs and via one of two trading methods: the order book or an RFQ that is transmitted to at least three other market participants on the SEF.[14] Since the trade execution requirement took effect, trades in five-year on-the-run and immediate off-the-run index CDSs on CDX.IG and CDX.HY have been subject to the requirement.[15] Block trades are exempt from the trade execution requirement.

The implementation of Dodd-Frank Act provisions for index CDSs was rolled out in stages over a period of about one year. For dealers the reporting requirement took effect on December 31, 2012 and the clearing requirement took effect on March 11, 2013. By the time the first SEFs started operating on October 2, 2013, the trade reporting and clearing require-

[12] See Part 50, Part 43, and Part 37 of Chapter I of Title 17 of the Code of Federal Regulations (17 CFR) and Section 2(h) of the Commodity Exchange Act (CEA).

[13] Block trades have notional amounts that exceed certain minimum block sizes and are exempt from immediate dissemination to protect liquidity providers in block-sized trades from front running. Minimum block sizes depend on the par spread and contract tenor (see Appendix F to Part 43 of Chapter I of 17 CFR for the mapping of spread-contract-tenor pairs to block sizes).

[14] For an interim one-year period, it was sufficient to transmit RFQs to at least two other participants.

[15] In addition, trades in five-year on-the-run and immediate off-the-run index CDSs on iTraxx Europe and iTraxx Europe Crossover are subject to the trade execution requirement. iTraxx Europe and iTraxx Europe Crossover are Markit's benchmark credit indices of investment-grade and high-yield credit risk in Europe.

ments were in effect for all market participants. Finally, the trade execution requirement took effect on February 26, 2014. Appendix A provides a timeline with additional details concerning the CFTC's implementation of Dodd-Frank Act provisions.

Through the introduction of SEFs and the requirement that they offer trading in order books, the new regulation had the potential to open up the index CDS market to all-to-all trading.[16] However, several years into the new regulatory regime, the index CDS market remains two-tiered and all-to-all trading has yet to materialize.

The D2C segment of the market migrated onto SEFs run by incumbent operators of D2C trading platforms where the vast majority of trades are executed via name-disclosed RFQs. These are Bloomberg SEF, ICE Swap Trade, MarketAxess SEF, and TW SEF; collectively called D2C SEFs. The D2D segment of the market migrated onto SEFs run by IDBs where most trades are executed on order books. These are GFI Swaps Exchange, ICAP SEF, tpSEF, and Tradition SEF; collectively called IDB SEFs.

Several reasons have been given for the persistence of the two-tiered market structure. At one end of the spectrum, some observers argue that this is the optimal structure of a market in which trades occur relatively infrequently and in very large sizes (see, e.g., Giancarlo (2015)). At the other end of the spectrum, some market participants argue that dealers try to build barriers to entry to the interdealer market (see, e.g., Managed Funds Association (2015)). One such barrier is post-trade name give-up on IDB SEFs; i.e., the practice of informing anonymously matched traders about the identity of their counterparty after the trade is executed. This makes participation on IDB SEFs unattractive for many clients because of the risk of uncontrolled information leakage of proprietary trading strategies.[17]

[16]Implicitly, the CFTC had hoped that the introduction of SEFs would push the index CDS market, and other active OTC derivatives markets, towards all-to-all trading. For instance, when discussing the benefits of SEF rules, the CFTC stated that the "...rules provide for an anonymous but transparent order book that will facilitate trading among market participants directly without having to route all trades through dealers." See 78 Federal Register at 33565 (Jun. 4, 2013).

[17]Trading via RFQ also entails a certain amount of information leakage, but in this case the client has control over which dealers receive the information. Because the vast majority of index CDSs are centrally cleared, there is no reason for post-trade name give-up from a counterparty risk perspective. However, some dealers

3 Data and Identification Algorithms

This section describes the transaction and quote data and the algorithms that identify SEFs and package transactions.

3.1 Data

Our empirical analysis is based on trades and quotes over a two-year period from October 2, 2013 to October 16, 2015. All trades are executed on SEFs. The transaction data come from the three SDRs that disseminate trade reports of index CDS transactions: the Bloomberg Swap Data Repository (BSDR), the Depository Trust & Clearing Corporation Data Repository (DDR), and the Intercontinental Exchange Trade Vault (ICETV). Trade reports contain execution timestamps, transaction prices, and trade sizes up to a cap of at least USD 100 million,[18] and they indicate whether the trade is centrally cleared, whether it features non-standard (or bespoke) contract terms, and whether it is subject to an end-user exception that exempts the trade from the clearing and trade execution requirements.[19] The trade reports also indicate whether the trade is executed on a SEF, but they do not specify which one. They also do not specify whether the trade is part of a package; i.e., a transaction that involves more than one index CDS or an index CDS and a related instrument, such as an index swaption or tranche swap (both of which are conventionally traded with delta, see below).[20] Fortunately, SEFs and package transactions can be identified from trade reports; the details of the respective identification algorithms are discussed in subsequent sections.

argue that name give-up is needed to prevent predatory trading (see, e.g., "How to Game a SEF: Banks Fear Arrival of Arbitrageurs," *Risk Magazine*, March 19, 2014).

[18] The actual cap size is the larger of USD 100 million and the minimum block size (see §43.4(h) of Chapter I of 17 CFR).

[19] This would be the case if one counterparty is a non-financial entity that uses the trade to hedge commercial risks (see Sections 2(h)(7) and 2(h)(8) of the CEA).

[20] There are other important trade characteristics that are not specified in the trade reports. For instance, trade reports do not specify whether the trade is buyer- or seller-initiated, whether it is D2C or D2D, and whether it is executed on an order book or via a RFQ.

Intraday composite bid and offer quotes for index CDSs come from Markit. These quotes constitute the main real-time reference in the index CDS market that is available to all market participants. The composites average over quotes of individual dealers that Markit parses from so-called dealer runs; i.e., e-mails that dealers send to their institutional clients throughout the trading day to keep them up to date with indicative quotes of index CDSs and other credit derivatives. A composite is computed whenever a dealer sends out a run and only the quotes from each dealer's latest run are eligible for composite computation.[21]

Figure 1 shows trades and Markit intraday mid-quotes on a representative trading day, May 6, 2015, for the five-year index CDS on the then on-the-run series of CDX.IG. There are 401 mid-quotes between 7:00 a.m. and 5:30 p.m., New York time, and 165 trades. Most striking are the trades at 64 bps and 66 bps that appear to be outliers in comparison to the other trades that tend to be relatively close to the mid-quote. After processing the data through our identification algorithms, these trades turn out to be delta hedges of index swaption trades, see below. Data processing also shows that, out of the 165 trades, 139 are executed on D2C SEFs (identified as D2C trades) and 26 are executed on IDB SEFs (identified as D2D trades).

[Figure 1 about here.]

3.2 Identification of SEFs

In devising the SEF identification algorithm, we use SEF-reported trading volumes from Clarus FT.[22] Each of the on-SEF trade reports must have been submitted by one of the eight aforementioned SEFs. Bloomberg SEF submits trade reports to the BSDR and ICE Swap Trade submits trade reports to the ICETV. The remaining SEFs submit trade reports

[21] Quotes from runs older than 15 minutes are discarded from the computation and a five-minute memory prevents repeated computations of the same composite.

[22] Clarus FT is the standard data source for SEF-reported daily trading volumes. In the Internet Appendix, we describe the Clarus FT data in detail.

to the DDR and the trade-report-submitting SEF can be identified based on the format of the trade report. Specifically, we associate with each SEF the format of trade reports whose aggregate trade size corresponds to the SEF-reported trading volume (the Internet Appendix contains the details).

Because of the two-tiered market structure, the SEF on which the trade took place reveals whether the trade is D2C or D2D. It should be emphasized that limiting the sample to trades executed on SEFs is not restrictive because our main analysis below focuses on trades in the most actively traded on-the-run and immediate off-the-run index CDSs. After February 26, 2014 trades in these index CDSs are required to be executed on SEFs. In the initial period from October 2, 2013 to February 25, 2014, on-SEF trade execution was non-mandatory but the majority of trades were executed on SEFs (the Internet Appendix contains additional details).

3.3 Identification of Package Transactions

We identify four popular types of package transactions: index rolls, curve trades, delta-hedged index swaptions, and delta-hedged index tranche swaps (the Internet Appendix contains the details). A typical index roll involves an on-the-run and an off-the-run index CDS with the same contract tenor. Protection is sold on one index series and simultaneously bought on the other. Index rolls are popular because many institutional investors like to maintain liquid credit exposure with a relatively constant maturity profile. We identify index rolls as simultaneously executed index CDS trades on the same SEF that have the same contract tenor and reference two different series of the same index.

A typical curve trade involves two index CDSs with different contract tenors.[23] Protection is sold on one contract tenor and simultaneously bought on the other. Curve trades are

[23]Typically, the underlying of both index CDSs is the same but there are also curve trades in which the two index CDSs reference different index series.

popular because they are relatively directional (index CDS term structures tend to become flatter when spreads widen and steeper when spreads contract; see, e.g., Erlandsson, Ghosh, and Rennison (2008)) and require less capital outlay than outright index CDS trades. We identify curve trades as simultaneously executed index CDS trades on the same SEF that have different contract tenors and reference the same index (but not necessarily the same index series).

We also account for the fact that index swaptions and tranche swaps are conventionally traded "with delta;" i.e., together with a delta hedge in the corresponding index CDS. Quotes of index swaptions and tranche swaps incorporate both the delta and the so-called "reference level" at which the delta hedge will be traded. Usually, the reference level is set close to the par spread at which the index CDS trades at the beginning of the trading day (see, e.g., Hünseler (2013)), but it might be updated throughout the trading day because of spread movements. For CDX.IG, the reference level is usually set in spread multiples of 0.5 bps.[24] We identify index swaption and tranche swap delta hedges as index CDS trades that have the same underlying index and contract tenor as an index swaption or tranche swap trade. Trade executions must be near simultaneous and notional amounts must be reconcilable with a delta that is quoted on the same trading day.

Index swaptions and tranche swaps can also be traded without delta, but usually at less favorable prices that incorporate the dealer's cost of establishing the hedge. Therefore, investors may find it beneficial to trade index swaptions and tranche swaps with delta and unwind the hedge themselves (see, e.g., Hünseler (2013)). We identify such delta unwinds as trades with the same transaction price and notional amount as a delta hedge of an index swaption or tranche swap trade that occurs on the same trading day and SEF.

Whether a trade is part of a package is important because package transactions are either quoted in relative terms (index rolls and curve trades) or along with a price-forming quote

[24]Because CDX.HY is quoted in terms of a price, the reference level is usually set in price multiples of 0.125%.

for another instrument (delta hedges of index swaption and tranche swap trades). Therefore, transaction prices on the individual index CDS legs of package transactions do not necessarily have to reflect the par spread at which outright trades in the respective index CDSs would be executed. This is clearly the case for most of the delta hedges in Figure 1.

3.4 SEF Order Flow

Table 1 displays descriptive statistics of the enriched transaction data that allows to distinguish between D2C and D2D trades and between outright trades and package transactions. Descriptive statistics are computed separately for D2C and D2D trades in CDX.IG (Panels A1 and A2, respectively) and CDX.HY (Panels B1 and B2, respectively) and, within these broad categories of trades, descriptive statistics are computed separately for trades executed on a given SEF.

[Table 1 about here.]

In terms of the notional amount traded, D2C trades in CDX.IG account for a daily trading volume of USD 9.843 billion, on average, and those in CDX.HY account for a daily trading volume of USD 3.705 billion, on average. In comparison, D2D trades in the two indices account for average daily trading volumes of USD 1.354 billion and USD 0.402 billion, respectively.[25] These averages appear in parenthesis in Table 1 because they are based on SEF-reported daily trading volumes from Clarus FT instead of transaction data. They cannot be reproduced with transaction data because trade reports contain capped trade sizes. Table 1 shows that 21.2% and 2.3% of D2C trades in CDX.IG and CDX.HY, respectively, are disseminated with capped trade sizes, while the corresponding numbers for D2D trades

[25] D2D trading accounts for 10% (for CDX.HY) to 12% (for CDX.IG) of total volume in the index CDS market. The International Swaps and Derivatives Association (2014, ISDA) estimates that, in case of interest rate swaps, D2D trading accounts for 35% of total volume. However, the ISDA (2014) argues that as much as two-thirds of D2D trading is due to non-price-forming trades, such as amendments, novations, and terminations, all of which are excluded from our sample. This brings the ISDA's (2014) estimate for interest rate swaps more in line with the one we find for index CDSs in our sample.

are 6.8% and 1.4%, respectively.[26] As a consequence, transaction-data-based average daily trading volumes are downward biased.[27]

The vast majority of trades are in the five-year contract tenor and around 90% of trades are in on-the-run index CDSs. Almost all trades have standardized contract terms and are centrally cleared.[28] Outright trades account for most of the trading volume and, among package transactions, index rolls are most popular, accounting for 5.0% and 8.9% (17.3% and 21.7%) of D2C (D2D) trading volume in CDX.IG and CDX.HY, respectively. The fact that there are virtually no D2D block trades, whereas about 20% of D2C trades are blocks is consistent with D2D trades occurring on order books. This is because block-sized trades executed on order books do not qualify as block trades.

As explained in Section 2.1, liquidity in the index CDS market concentrates in on-the-run index CDSs and, in particular, those with a five-year contract tenor. Indeed, Table 2 shows that in the D2C segment, outright trades in five-year on-the-run index CDSs account for 90.0% and 91.2% (88.5% and 84.6%) of trades (of trading volume) in CDX.IG and CDX.HY, respectively. In the D2D segment, fractions of trades and trading volumes are slightly lower.

[26] In comparison to trades in CDX.IG, the percentage of trades that are disseminated with capped trade sizes is lower for trades in CDX.HY because the latter tend to be of smaller size (in absolute terms and relative to the cap). The median size of trades in CDX.IG is five times that of trades in CDX.HY but caps typically differ by USD 10 million only (for trades in CDX.IG the cap is typically USD 110 million and for trades in CDX.HY the cap is typically USD 100 million).

[27] The actual volumes allow to impute by how much the size of trades that are disseminated with capped trade sizes exceeds the cap on average. For instance, the size of D2C trades in CDX.IG that are disseminated with capped notional amounts exceeds the cap by USD 141.17 ($= 511 \times (9,843 - 6,433)/(0.212 \times 58,222)$) million, on average (511 is the number of trading days in the sample period). Most of these trades are capped at USD 110 million, suggesting that, conditional on being capped, the average trade size of D2C trades in CDX.IG is approximately USD 250 million. Similarly, conditional on being capped, the average trade size of D2D trades in CDX.IG is approximately USD 200 million. For CDX.HY, most trades are capped at USD 100 million and, conditional on being capped, the average trade sizes of D2C and D2D trades in CDX.HY are approximately USD 225 million and USD 160 million, respectively.

[28] Loon and Zhong (2016) find that bespoke contract terms, central clearing, and a counterparty that qualifies as an end-user are trade characteristics that significantly affect transaction costs of index CDSs. These characteristics cannot be a main driver of potential transaction cost differences between D2C and D2D trades because the vast majority of both D2C and D2D trades are non-bespoke and centrally cleared. We observe an increasing share of end-user exempt transactions prior to February 10, 2014 (around 80% of trades on February 7, 2014 are end-user exempt) and not a single end-user exempt trade afterwards. We are not aware of no-action reliefs issued by the CFTC that expired on February 10, 2014 and could explain the decline.

Outright trades in other index CDSs account for relatively small fractions of trades and trading volumes. Most of the other outright trades are in five-year immediate off-the-run index CDSs (not shown).

[Table 2 about here.]

Trades in five-year on-the-run and immediate off-the-run index CDSs prominently figure among package transactions as well. Trades that are part of index rolls between these index CDSs account for most packaged D2C trades and a large fraction of packaged D2D trades.

4 Transaction Cost Comparison

In order to analyze what determines transaction costs of D2C and D2D trades in the two-tiered index CDS market, we focus on outright trades in on-the-run index CDSs and index rolls between on-the-run and immediate off-the-run index CDSs, all with a five-year contract tenor.[29] As highlighted by the preceding discussion, together these trades account for the majority of both trades and trading volumes in the index CDS market.

4.1 Transaction Cost Decomposition

We measure transaction costs by effective half-spreads with respect to Markit's intraday mid-quote. Recognizing that spreads reflect both dealer revenue and the information content of trade, we further decompose effective half-spreads into realized half-spreads and price impacts. Specifically,

$$\underbrace{q_t(p_t - m_t)}_{=\text{EffcSprd}_t} = \underbrace{q_t(p_t - m_{t+\Delta})}_{=\text{RlzdSprd}_t} + \underbrace{q_t(m_{t+\Delta} - m_t)}_{=\text{PrcImp}_t}, \tag{1}$$

[29] In the Internet Appendix, we provide an analysis of outright trades in immediate off-the-run index CDSs. Results are consistent with those of outright trades in on-the-run index CDSs. For the other trade types there are too few trades to reliably measure transaction costs.

where p_t is the transaction price of the t-th trade in index CDS i (we suppress dependence on i because all our analyses separately focus on one type of trade in CDSs on a given index), m_t is the latest mid-quote in the 15-minute period prior to trade execution, and $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. In case of index rolls, p_t is the difference in transaction prices of the involved on-the-run and immediate off-the-run index CDSs,[30] and m_t ($m_{t+\Delta}$) is the corresponding difference in mid-quotes.[31] Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm and equals $+1$ (-1) in case of protection-buyer-initiated (protection-seller-initiated) trades.

Assuming that one counterparty of each trade is a liquidity providing dealer, Equation (1) can be interpreted as follows: the effective half-spread measures the liquidity providing dealer's revenue if she were able to immediately close her position at the prevailing mid-quote. If instead it takes the dealer Δ units of time to close her position (and again assuming that she is able to do so at the then prevailing mid-quote), her revenue is the realized half-spread. The revenue is less than the effective half-spread if the price moves against the dealer while she is reversing the trade over time. Price impact captures such trade-induced price moves or adverse selection costs.

4.2 Descriptive Statistics

Figure 2 shows weekly averages of effective half-spreads, realized half-spreads, and price impacts of outright D2C and D2D trades. Panels A and B show that, for both indices, D2C trades have consistently higher effective half-spreads than D2D trades. Panels E and F show

[30] Following market convention, p_t is the par spread of the on-the-run index CDS minus the par spread of the immediate off-the-run index CDS.

[31] Specifically, m_t is the corresponding difference in the latest mid-quotes prior to trade execution, with the later of the two quotes occurring in the 15-minute period prior to trade execution and the earlier of the two quotes occurring within 15 minutes from the later. Similarly, $m_{t+\Delta}$ is the corresponding difference in mid-quotes that occur after trade execution, with the later of the two quotes being the first quote on either of the two index CDSs that occurs in the 15-minute period that follows trade execution by 15 minutes and the earlier of the two quotes being the latest quote on the other index CDS that occurs within 15 minutes from the later of the two quotes.

that D2C trades also have consistently higher price impacts than D2D trades, suggesting that transaction cost differentials reflect differences in price impacts. Panels C and D are consistent with this in that there are no systematic differences between the realized half-spreads of D2C and D2D trades.

[Figure 2 about here.]

Table 3 displays average effective half-spreads, realized half-spreads, and price impacts of outright trades and index rolls. For outright trades the results confirm the impression from Figure 2. In case of CDX.IG, average effective half-spreads are 0.137 bps and 0.088 bps for D2C and D2D trades, respectively, with the difference of 0.049 bps being statistically significant. The corresponding numbers for CDX.HY are 0.674 bps and 0.402 bps, respectively, with the difference of 0.273 bps again being statistically significant.

[Table 3 about here.]

These transaction cost differentials are largely due to D2C trades having higher price impacts than D2D trades. For CDX.IG, average price impacts are 0.106 bps and 0.063 bps for D2C and D2D trades, respectively, with the difference of 0.043 bps being statistically significant. The corresponding numbers for CDX.HY are 0.508 bps and 0.246 bps, respectively, with the difference of 0.262 bps again being statistically significant. After taking price impact into account, there is no significant difference in average per trade revenues (as captured by realized half-spreads) across D2C and D2D trades.

As explained in Section 3.3, index rolls are liquidity motivated. Consistent with a non-informational motive for trade, Table 3 shows that index rolls have lower average effective half-spreads and price impacts than outright trades. For index rolls there are also no significant differences in average transaction costs and price impacts across D2C and D2D trades.

Table 4 focuses on outright trades only and displays average effective half-spreads, realized half-spreads, and price impacts by quartiles of the trade size distribution. In case of both indices and regardless of the quartile of the trade size distribution, effective half-spreads and price impacts of D2C trades are significantly higher than those of D2D trades.

Effective half-spreads of D2C trades in both indices increase with trade size which is in contrast to evidence from other dealer markets, such as the corporate and municipal bond markets, where transaction costs typically decrease with trade size; see, e.g., Bessembinder, Maxwell, and Venkataraman (2006), Edwards et al. (2007), Goldstein et al. (2007), Harris and Piwowar (2006), and Green, Hollifield, and Schürhoff (2007). This reflects structural differences between the two markets: the index CDS market is purely institutional with professional investors trading in large sizes; in contrast, there is retail participation in bond markets with relatively unsophisticated market participants trading in small sizes and with dealers who seem to exert market power.

[Table 4 about here.]

Price impact of D2C trades in both indices tends to increase with trade size as well but only up to the third quartile of the trade size distribution. The decrease of price impact for block-sized trades in the fourth quartile of the trade size distribution is consistent with block trade provisions that aim at mitigating the price impact of block-sized trades.

4.3 Accounting for Trade Characteristics and Market Conditions

The evidence thus far does not account for the possibility that different trade characteristics (other than trade size) of D2C and D2D trades and potentially different market conditions during which these trades are executed can explain the observed differences in average effective half-spreads and price impacts. In order to rule out such possibilities (or selection biases), we estimate selection-bias-corrected averages from trade-by-trade regressions that control for trade characteristics and market conditions, and we analyze pairs of trades with matching trade characteristics that are executed at around the same time.

Trade-By-Trade Regressions

We estimate the following trade-by-trade regressions:[32]

$$y_t = \alpha_{\text{D2C}}\text{D2C}_t + \alpha_{\text{D2D}}\text{D2D}_t + \beta' X_t + \epsilon_t, \tag{2}$$

where y_t is the either the effective half-spread, the realized half-spread, or the price impact of the t-th trade in index CDS i (as before, we suppress dependence on i), D2C_t and D2D_t are dummy variables for D2C and D2D trades, respectively, and X_t is a vector of control variables. Continuous control variables are stated in deviations from their sample means for ease of interpretation.

The continuous control variables include the bid-ask spread of the latest quote for the five-year on-the-run index CDS, the corresponding mid-quote, and the end-of-day implied volatility of the at-the-money three-month index swaption on the five-year on-the-run index CDS. In addition, we include a set of dummy variables for trades with sizes in the second, third, and fourth quartile of the trade size distribution, and a dummy variable for trades with transaction prices at which reference levels of index swaption and tranche swap trades tend to be set. The continuous control variables proxy for the prevailing market conditions at trade execution. We account for trade size because Table 4 shows that D2C transaction costs and price impacts tend to increase with trade size, and we include a reference level dummy to account for potentially unidentified index swaption and tranche swap delta hedges.[33]

Due to demeaned continuous control variables, α_{D2C} and α_{D2D}, respectively, estimate

[32] Comparing regression-based methods of addressing selection biases, Bessembinder (2003) concludes "...while it is important to control for selection biases, the specific method of control has little practical effect on inference regarding market quality. In particular, the simple technique of including in a regression framework economic variables that are known to be related to trade execution costs appears to provide selectivity bias corrections that work as well as more complex two-stage methods."

[33] One reason for unidentified delta hedges is that we only identify delta hedges of on-SEF index swaption and tranche swap trades, but neither swaptions nor tranche swaps have to be traded on SEFs. Nevertheless, the delta hedges of off-SEF index swaption and tranche swap trades would typically be executed on SEFs in order to satisfy other regulatory requirements.

average effective half-spreads (or, depending on the dependent variable used, realized half-spreads or price impacts) of outright D2C and D2D trades that have trade sizes in the first quartile of the trade size distribution and non-reference-level transaction prices, and that are executed when average market conditions prevail. Note that the estimates are directly comparable with those reported in Table 3 because the latter correspond to coefficient estimates of a restricted version of Equation (2) which excludes control variables.

Table 5 displays regression results. Accounting for trade characteristics and market conditions does not materially change the conclusions from Table 3. For CDX.IG, the difference in effective half-spreads of D2C and D2D trades is 0.033 bps (in comparison to 0.049 bps in Table 3) and statistically significant. For CDX.HY, the difference is 0.219 bps (in comparison to 0.273 bps in Table 3) and statistically significant. For both indices, the estimated regression coefficients show that transaction costs increase with trade size, when bid-ask spreads widen (i.e., when liquidity deteriorates), and when implied volatility increases. In addition, trades with reference level transaction prices are more expensive.

[Table 5 about here.]

Again, transaction cost differentials are largely due to differences in price impact. For CDX.IG, the difference in price impacts of D2C and D2D trades is a statistically significant 0.027 bps, accounting for most of the 0.033 bps difference in effective half-spreads. For CDX.HY, the difference in price impacts is a statistically significant 0.218 bps, accounting for almost the entire 0.219 bps difference in effective half-spreads. It follows that there are no significant differences in realized half-spreads of D2C and D2D trades. For both indices, the estimated regression coefficients show that price impacts increase with quoted bid-ask spread and implied volatility. Price impacts tend to increase with trade size; however, for CDX.HY, block-sized trades have lower price impacts than large-sized trades in the third quartile of the trade size distribution.

Finally, consistent with a non-informational motive for trade, regression results for index rolls (displayed in Table 6) do not reveal significant differences in effective half-spreads and price impacts of D2C and D2D index rolls.[34] The estimated regression coefficients show that index roll transaction costs are insensitive to the size rolled and increase when bid-ask spreads widen.

[Table 6 about here.]

Matched Pair Analysis

Alternatively, trade characteristics and market conditions can be controlled for by focussing on pairs of D2C and D2D trades with matching trade characteristics that are executed relatively close in time. To this end, we focus on those outright D2D trades for which we are able to find at least one matching outright D2C trade in the same index CDS and with trade size in the same quartile of the trade size distribution (or, in one analysis, with exactly the same trade size) that occurs within a 15-minute window bracketing the execution of the D2D trade. In case of more than one matching D2C trade, the match is a hypothetical trade with effective half-spread, realized half-spread, and price impact corresponding to the average value among matching D2C trades.[35]

Table 7 shows the results. In case of CDX.IG, 52.7% of D2D trades have a matching D2C trade with trade size in the same quartile of the trade size distribution, and 38.0% of D2D trades have a matching D2C trade with exactly the same trade size. The pairs of trades with exactly matching trade sizes consist of D2C trades with an average effective half-spread of 0.124 bps (which is slightly less than in the full sample) and D2D trades with an average effective half-spread of 0.097 bps (which is slightly more than in the full sample). The average

[34] Because trade sizes of index rolls are relatively large (e.g., more than 50% of CDX.IG index rolls have capped on-the-run leg trade sizes), the regressions for index rolls only include a dummy variable for block-sized index rolls which is based on the trade size of the on-the-run leg.

[35] Similar matching methods have, e.g., been used by Lee (1993) to construct a sample of New York Stock Exchange trades that match the characteristics of a given set of OTC and regional exchange equity trades.

paired difference in effective half-spreads of matching D2C and D2D trades is 0.027 bps and statistically significant. The average paired difference in price impacts is 0.019 bps and also statistically significant. There is no significant difference in realized half-spreads of matching D2C and D2D trades.

[Table 7 about here.]

Most of these observations carry over to pairs of matched trades with trade sizes in the same quartile of the trade size distribution and to pairs of matched trades in CDX.HY. Overall, the results of the matched pair analysis are consistent with those of the trade-by-trade regressions, both in terms of the magnitude of differences between D2C and D2D trades and in terms of inference.

In the Internet Appendix, we show that our results are robust to using an alternative mid-quote from Credit Market Analysis. We also show that our results are robust to using both shorter and longer time periods over which to compute realized half-spreads and price impacts and to using alternative time windows when constructing pairs of trades with matching characteristics.

5 The Dynamics of Trades and Quotes

The evidence thus far has revealed that D2C trades have both larger transaction costs and higher price impacts than D2D trades. In order to investigate the price discovery process that gives rise to the differential price impact, we analyze a VAR model that accounts for the two-tiered structure of the index CDS market and the market-specific quote provision in form of dealer runs. In comparison to the relatively simple ad hoc decomposition of the effective half-spread that we used in the previous section, the VAR model accounts for persistence in order flow and dynamic interactions between quote revisions and trades.

5.1 VAR Framework and Model Estimation

Specifically, we estimate an event-time VAR model for mid-quote changes, Δm_t, and D2C- and D2D-trade-related variables, x_t^{D2C} and x_t^{D2D}, respectively; that is,

$$\Delta m_t = \sum_{j=1}^{10} \alpha_j \Delta m_{t-j} + \sum_{j=0}^{10} \beta_j x_{t-j}^{\text{D2C}} + \sum_{j=0}^{10} \gamma_j x_{t-j}^{\text{D2D}} + \epsilon_t^{\Delta m}, \tag{3a}$$

$$x_t^{\text{D2C}} = \sum_{j=1}^{10} \delta_j \Delta m_{t-j} + \sum_{j=1}^{10} \zeta_j x_{t-j}^{\text{D2C}} + \sum_{j=1}^{10} \eta_j x_{t-j}^{\text{D2D}} + \epsilon_t^{\text{D2C}}, \tag{3b}$$

$$x_t^{\text{D2D}} = \sum_{j=1}^{10} \kappa_j \Delta m_{t-j} + \sum_{j=0}^{10} \lambda_j x_{t-j}^{\text{D2C}} + \sum_{j=1}^{10} \rho_j x_{t-j}^{\text{D2D}} + \epsilon_t^{\text{D2D}}, \tag{3c}$$

where t indexes the t-th quote revision (i.e., computation of a composite quote) and x_t^{D2C} (x_t^{D2D}) is the number of signed D2C (D2D) trades that occur between the $t-1$-th and t-th quote revision (i.e., x_t^{D2C} and x_t^{D2D} are sums of the above trade direction indicators, q_u, with u between the calendar time of the $t-1$-th and t-th quote revision). The error terms, $\epsilon_t^{\Delta m}$, ϵ_t^{D2C}, and ϵ_t^{D2D}, are uncorrelated because we resolve contemporaneous effects by including contemporaneous trade-related variables in Equations (3a) and (3c).[36] Intuitively, the D2C-trade-related variable may contemporaneously affect the D2D-trade-related variable when dealers immediately offload inventory in the interdealer market, and D2C- and D2D-trade-related variables may contemporaneously affect mid-quote revisions when dealers immediately adjust quotes in response to trades.[37]

Hasbrouck (1991a, 1991b) argues that VAR systems like the one in Equations (3a) to (3c) provide a flexible and robust framework in which permanent (information-driven) and transitory (microstructure-driven) quote changes can be separated. Specifically, because microstructure effects fade away in the long-run, the system-implied long-run cumulative

[36] Moreover, error terms are assumed to be serially uncorrelated and homoscedastic.
[37] Our results are not sensitive to how we resolve contemporaneous effects between D2C- and D2D-trade-related variables. The same results obtain when we instead allow the D2D-trade-related variable to contemporaneously affect the D2C-trade-related variable.

mid-quote change in response to a shock of trade-related variables measures the information content of trade (or the price impact). The latter can be conveniently estimated from the vector moving average (VMA) representation of the VAR model; that is,

$$\Delta m_t = \epsilon_t^{\Delta m} + a_1 \epsilon_{t-1}^{\Delta m} + \cdots + b_0 \epsilon_t^{\text{D2C}} + b_1 \epsilon_{t-1}^{\text{D2C}} + \cdots + c_0 \epsilon_t^{\text{D2D}} + c_1 \epsilon_{t-1}^{\text{D2D}} + \cdots , \tag{4a}$$

$$x_t^{\text{D2C}} = d_1 \epsilon_{t-1}^{\Delta m} + d_2 \epsilon_{t-2}^{\Delta m} + \cdots + \epsilon_t^{\text{D2C}} + z_1 \epsilon_{t-1}^{\text{D2C}} + \cdots + h_1 \epsilon_{t-1}^{\text{D2D}} + h_2 \epsilon_{t-2}^{\text{D2D}} + \cdots , \tag{4b}$$

$$x_t^{\text{D2D}} = k_1 \epsilon_{t-1}^{\Delta m} + k_2 \epsilon_{t-2}^{\Delta m} + \cdots + l_0 \epsilon_t^{\text{D2C}} + l_1 \epsilon_{t-1}^{\text{D2C}} + \cdots + \epsilon_t^{\text{D2D}} + r_1 \epsilon_{t-1}^{\text{D2D}} + \cdots . \tag{4c}$$

It immediately follows from Equation (4a), that the price impact of a single protection-buyer-initiated D2C trade is

$$\Lambda_{\text{D2C}} = \lim_{n \to \infty} \sum_{j=0}^{n} \mathbb{E}\left[\Delta m_{t+j} \middle| \Omega_t^{\text{D2C}} \right] = \lim_{n \to \infty} \sum_{j=0}^{n} b_j = \sum_{j=0}^{\infty} b_j , \tag{5}$$

where $\Omega_t^{\text{D2C}} = \left\{ \epsilon_t^{\text{D2C}} = 1,\ \epsilon_t^{\Delta m} = \epsilon_t^{\text{D2D}} = 0,\ \epsilon_s^{\Delta m} = \epsilon_s^{\text{D2C}} = \epsilon_s^{\text{D2D}} = 0,\ s < t \right\}$ denotes the event of an isolated unit-sized shock of the D2C-trade-related variable.[38] Similarly, the price impact of a single protection-buyer-initiated D2D trade is $\Lambda_{\text{D2D}} = \sum_{j=0}^{\infty} c_j$.

Moreover, the VAR model is consistent with a fairly general unobserved component model. Accordingly, $m_t = \bar{p}_t + s_t$, where $\bar{p}_t$ is the (unobservable) efficient price and s_t is (unobservable) microstructure noise. The former is assumed to follow a random walk (which is, e.g., consistent with $\bar{p}_t$ being the conditional expectation of some future payoff) while the latter is a generic covariance stationary process with mean zero (which is, e.g., consistent with the transient nature of most microstructure effects, such as inventory-control-driven price pressure). Hasbrouck (1991b) shows that the variance of efficient price innovations, $\sigma^2_{\Delta \bar{p}}$, can be explicitly expressed in terms of error term variances and VMA-representation

[38] A single protection-buyer-initiated D2C trade is an event in Ω_t^{D2C} but obviously not the only event that gives rise to a unit-sized shock of the D2C-trade-related variable. For instance, occurrence of two protection-buyer-initiated D2C trades and one protection-seller-initiated D2C trade between the $t-1$-th and t-th quote revision also result in a unit-sized shock of the D2C-trade-related variable.

parameters; that is,

$$\sigma^2_{\Delta\bar{p}} = \left(\sum_{j=0}^{\infty} a_j\right)^2 \sigma^2_{\Delta m} + \left(\sum_{j=0}^{\infty} b_j\right)^2 \sigma^2_{\text{D2C}} + \left(\sum_{j=0}^{\infty} c_j\right)^2 \sigma^2_{\text{D2D}}, \tag{6}$$

where $\sigma^2_{\Delta m} = \mathbb{V}\big(\epsilon_t^{\Delta m}\big)$, $\sigma^2_{\text{D2C}} = \mathbb{V}\big(\epsilon_t^{\text{D2C}}\big)$, and $\sigma^2_{\text{D2D}} = \mathbb{V}\big(\epsilon_t^{\text{D2D}}\big)$. Equation (6) reflects a decomposition of efficient price innovations into three mutually orthogonal components: a trade-unrelated component with variance given by the first term on the right hand side of Equation (6), and two trade-related components with variances given by the second and third term. The first trade-related component is associated with D2C trades and the second one is associated with D2D trades. Equation (6) is the basis of our price discovery metric, Hasbrouck's (1991b) R^2, that expresses each component's variance as a fraction of $\sigma^2_{\Delta\bar{p}}$.

We estimate the VAR model using all quote changes between 7:00 a.m. and 5:30 p.m., New York time, during the sample period.[39] We splice together intraday quote changes of five-year on-the-run index CDSs and the corresponding numbers of signed outright trades in order to create a continuous vector-valued time series from which we can estimate the VAR model. We exclude quote changes that span long periods of time presumably because of technical issues with the composite computation.[40] Finally, we winsorize quote changes at the 0.1% and 99.9% quantile of their distribution.

5.2 Results

Panels A1 and A2 of Table 8 display VAR coefficient estimates for CDX.IG and CDX.HY, respectively. The results for both indices are similar and, therefore, our discussion focuses on CDX.IG. The significant coefficients of contemporaneous trade-related variables in Equa-

[39]When estimating the VAR model, we assume that the system is in steady-state at the beginning of each trading day.

[40]The fact that, over these time spans, there are typically neither quotes for CDX.IG nor for CDX.HY suggests technical disruptions.

tion (3a) suggest that dealers immediately raise mid-quotes by 0.009 bps and 0.003 bps in response to single protection-buyer-initiated D2C and D2D trades, respectively. Mid-quotes tend to be raised further in subsequent revisions due to the generally positive and significant coefficients of lagged variables in the equation (the table reports sums of coefficients of lagged variables and the corresponding t-statistics). The generally positive and significant coefficients of lagged D2C-(D2D-)trade-related variables in Equation (3b) (Equation (3c)) indicate positively autocorrelated D2C (D2D) trades. This reflects persistence in order flow, a pervasive feature of trade in financial markets.[41] Coefficients of contemporaneous and lagged D2C-trade-related variables in Equation (3c) are generally positive and significant, which is consistent with dealers hedging client trades in the interdealer market.

[Table 8 about here.]

The generally positive coefficients of lagged mid-quote changes in Equation (3b) suggest that quote changes are positively related to D2C trades. This is in contrast to the negative relation implied by inventory control considerations of an individual dealer who sets quotes so as to elicit client trades in the direction of inventory (i.e., who reduces quotes to elicit protection-buyer-initiated client trades when being a net protection buyer, and vice versa, when being a net protection seller). Instead, the positive relation may reflect momentum-driven trading by clients.

Granger causality tests reveal that D2C- and D2D-trade-related variables are characterized by one-way Granger causality from D2C trades to D2D trades. This is consistent with inventory management taking place in the interdealer market. Many market participants, in fact, view D2D trades as primarily hedging motivated. In support of this view, price discovery fractions of D2D trades in Panel C of Table 8 are virtually zero.

[41] Persistence in order flow has been found to characterize trade of many financial securities after Hasbrouck and Ho (1987) provided initial evidence for U.S. equities.

Figure 3 shows trade-induced cumulative quote revisions implied by the estimated VAR model. Specifically, the figure tracks the cumulative quote revision following single protection-buyer-initiated D2C and D2D trades, respectively. Consistent with the evidence based on the simple price impact measure of Section 4, we find that a single protection-buyer-initiated D2C trade has a larger cumulative effect on quotes than a single protection-buyer-initiated D2D trade. A formal statistical test regarding the ultimate price impact of a trade—i.e., the long-run limit of the cumulative quote revisions exhibited in Figure 3—is provided in Panel B of Table 8 and rejects the hypothesis of identical price impacts of D2C and D2D trades.

[Figure 3 about here.]

We relegate estimation of VAR model specifications that take trade size into account to the Internet Appendix. The results we obtain are consistent with the ones we report here. When estimating alternative VAR model specifications, we observe that the use of trade size does not add to the explanatory power of VAR models. This is reminiscent of Jones, Kaul, and Lipson (1994) who find that in the equity market trade size has little incremental explanatory power above that contained in the number of transactions.

6 Trading Protocols and Dealer Profits

While trading in the D2C segment is almost exclusively via RFQ, a number of different trading protocols are used in the interdealer market. Of particular interest are mid-market matching and workup. The distinctive feature of these two trading protocols is that trade occurs through size discovery; i.e., through quantity exchange at a fixed price (see, e.g., Duffie and Zhu (2015)). Because the price at which the exchange takes place is fixed the price is insensitive to price pressure and allows for exchange of potentially large quantities with little price impact.

We use unique order-book data from the main IDB SEF, the GFI Swaps Exchange, to investigate how transaction costs and price impact vary across trading protocols.[42] We also use this data to estimate dealer profits from liquidity provision.

6.1 Size-Discovery Trading Protocols

In addition to a standard limit order book and RFQ (both of which are price-discovery trading protocols), the GFI Swaps Exchange offers both matching and workup trading protocols. For five-year on-the-run index CDSs, the predominant matching mechanism is continuous mid-market matching. The mid-market level is set by a GFI broker and is usually somewhere between the best bid and offer on the limit order book but does not necessarily have to coincide with the mid-point implied by the best bid and offer. The mid-market level is displayed on the trading screen that shows the limit order book, and the color in which the mid-market level is displayed informs market participants about whether there is interest for matching or not. Market participants are not informed about the direction and size of unfilled interests but they know that interests must be at least of a minimum size.[43] Any opposing interests for matching at the mid-market level immediately result in a trade.

Workup sessions on the GFI Swaps Exchange are initiated by trades in the limit order book. During these sessions, the parties to the initiating trade and other market participants joining the trade can work up the size of the trade by submitting size orders that, in case of a match, result in a trade at the transaction price of the initiating trade. The aggressor and liquidity provider of the initiating trade are privileged by means of a 10-second exclusivity period during which they are the only market participants who can work up trade size. The exclusivity period is followed by a public period during which other market participants can

[42]Focusing on trades executed on the GFI Swaps Exchange is not restrictive because it is the IDB SEF facilitating most of the D2D trading volume (see Table 1). Other IDB SEFs also offer matching and workup, but order-book data are unavailable.

[43]Current minimum sizes are USD 25 million for CDX.IG and USD 10 million for CDX.HY.

join the trade. The public period lasts for at least 30 seconds with any workup during the public period automatically extending the workup session. The session terminates 40 seconds after the initiating trade or, in case of being extended, 30 seconds after the last workup. In contrast to continuous mid-market matching, market participants are informed about the direction and size of unfilled interests.

6.2 Data and Identification of Mid-Market Matches and Workups

The GFI data consist of the best bid and offer quotes that rest on the limit order book of the GFI Swaps Exchange. In addition, the data include the mid-market levels that GFI brokers set for mid-market matching. From this data, we identify trades in the limit order book, mid-market matches, and workups (the Internet Appendix contains the details). Trades that are not identified as belonging to any of the three categories are subsumed into their own category. Some of these trades are voice-brokered RFQs, while others result from unrecorded mid-market levels.

Table 9 shows volume shares of the different trade categories. We separately report volume shares for outright trades in five-year on-the-run and other index CDSs, for index rolls between five-year on-the-run and immediate off-the-run index CDSs, and for other package transactions (excluding index swaption and tranche swap delta hedges for which we are unable to identify the trading protocol). For five-year on-the-run index CDSs, mid-market matches account for 52.2% and 58.6% of trading volume in case of CDX.IG and CDX.HY, respectively. Trades in the limit order book account for 19.2% and 15.8% of trading volume in these contracts and about the same share of volume is traded in ensuing workup sessions.[44] Together size-discovery trading protocols account for the majority of trading volume in five-year on-the-run index CDSs, with aggregate volume shares of 72.1% and 74.2% in case of CDX.IG and CDX.HY, respectively.

[44] About half of the five-year on-the-run trades in the limit order book are subsequently worked up.

[Table 9 about here.]

6.3 Transaction Costs Across Trading Protocols

In order to compare effective half-spreads, realized half-spreads, and price impacts across trading protocols, we estimate trade-by-trade regressions similar to those in Equation (2). As before, we focus on outright trades in five-year on-the-run index CDSs and, for comparability with previous results, we continue to compute half-spreads and price impacts with respect to Markit's intraday mid-quote. Specifically, we estimate

$$y_t = \alpha + \beta_{\text{MTCH}}\text{MTCH}_t + \beta_{\text{WRKUP}}\text{WRKUP}_t + \beta_{\text{UNID}}\text{UNID}_t + \gamma' X_t + \epsilon_t, \tag{7}$$

where y_t and X_t are defined as before and MTCH_t, WRKUP_t, and UNID_t are dummy variables for mid-market matches, workups, and trades with unidentified trading protocol. Thus, α estimates the average effective half-spread (or, depending on the dependent variable used, realized half-spread or price impact) of an outright limit-order-book trade with trade size in the first quartile of the trade size distribution that is executed when average market conditions prevail, and βs estimate effective half-spread differences with respect to limit-order-book trades.

Table 10 displays regression results. First, compare limit-order-book trades and mid-market matches. Effective half-spreads are significantly lower for mid-market matches. This is unsurprising as the mid-market level is usually somewhere between the best bid and offer resting on the limit order book. More importantly, price impacts are significantly lower for mid-market matches, and there are no significant differences in realized half-spreads. That is, we observe a partial segmentation of the order flow, with a higher proportion of uninformed trades being executed via mid-market matching. This is consistent with Zhu's (2014) model of strategic venue selection by informed and liquidity traders. In his model, traders optimally choose between sending orders to a mid-point dark pool (roughly equivalent to continuous mid-market matching) and executing against limit orders. Sending an order to a dark pool involves a trade-off between potential price improvement and the risk of no execution. In equilibrium, liquidity traders prefer the dark pool, while informed traders prefer the certainty of executing against limit orders.

[Table 10 about here.]

Next, compare limit-order-book trades and workups. There are no significant differences in effective half-spreads. This is by design because workups are executed at the transaction prices of the initiating limit-order-book trades. There are also no significant differences in price impacts. Because a workup follows the initiating limit-order-book trade very closely in time, and because of the 15-minute period over which price impact is measured, the price impact of a workup will include most of the price impact of the initiating limit-order-book trade. The result, therefore, indicates that the additional price impact of a workup is close to zero.

To further explore differences in price impacts across trading protocols, we extend the VAR model in Section 5 with separate D2D-trade-related variables for limit-order-book trades, mid-market matches, workups, and the category of trades with unidentified trading protocol. These trade-related variables are defined for trades that are executed on the GFI Swaps Exchange only and other D2D trades are ignored in the analysis. Mid-quote changes and the D2C-trade-related variable are the same as before. We resolve contemporaneous effects between D2D-trade-related variables by allowing mid-market matches to contemporaneously affect the other D2D-trade-related variables, limit-order-book trades to contemporaneously affect workups and trades with unidentified trading protocol, and workups to contemporaneously affect trades with unidentified trading protocol. The causal ordering imposed is inconsequential because contemporaneous effects are negligible among all D2D-trade-related variables other than limit-order-book trades and workups for which the ordering is determined by the design of the trading protocol.[45]

Figure 4 shows cumulative quote revisions in response to buyer-initiated trades. A limit-order-book trade has the highest price impact; indeed, the price impact is similar to that of a D2C trade. A mid-market match has significantly lower price impact than a trade in the limit order book consistent with Table 10. Finally, the VAR model separates the price impact of a workup from that of the initiating limit-order-book trade, and the figure shows that a workup has very low price impact (essentially zero in case of CDX.HY). That a workup has significantly lower price impact than the initiating limit-order-book trade is consistent with evidence from the interdealer Treasury market reported in Fleming and Nguyen (2015).

[Figure 4 about here.]

Overall, our results show that the average transaction cost and price impact of D2D trades reported in Sections 4 and 5 mask significant heterogeneity across trading protocols with size-discovery protocols attracting liquidity-motivated trading.

6.4 Estimates of Profits from Liquidity Provision

We use the GFI data to estimate dealer profits from liquidity provision in five-year on-the-run index CDSs. Specifically, we assume that dealers provide immediacy on D2C SEFs and close their positions on the GFI Swaps Exchange. For each index we compute, day by day, the trade-size-weighted average profits from all D2C trades and multiply them by the aggregate trading volumes on D2C SEFs (from Clarus FT). Our estimates of profits from liquidity provision are sample means of daily profits computed in this way. In computing per trade profits, we consider two scenarios: first, that liquidity providers are able to immediately close

[45]We estimated VAR models with contemporaneous effects corresponding to each possible causal ordering among D2D-trade-related variables in which workups immediately follow limit-order-book trades. The cumulative effects implied by the six VAR models are visually indistinguishable.

D2C trades at the mid-market level that prevails at trade execution. Second, that liquidity providers are able to immediately close protection-buyer-initiated (protection-seller-initiated) D2C trades at the best offer (bid) that prevails at trade execution on the order book.[46]

In the first scenario estimated profits are USD 0.433 million and USD 0.808 million per day in case of CDX.IG and CDX.HY, respectively, or USD 1.241 million per day in total. However, this presumes that the quoted mid-market level is executable, which is only the case if there are opposing interests for matching. In the second scenario that uses executable bid and offer quotes, estimated profits are negative.[47] This suggests that dealers only make profits through their willingness to bear inventory risk (see, e.g., Grossman and Miller (1988)).

The results show that clients who value immediacy would typically not be able to reduce transaction costs by executing trades on the limit order book of the GFI Swaps Exchange. Indeed, 96.0% and 96.6% of the D2C trades in CDX.IG and CDX.HY, respectively, are executed at prices that are strictly more favorable than the contemporaneous best bid or offer.[48] Transaction costs can only be reduced at the cost of execution risk either through limit orders or through mid-market matching.

[46] We require mid-market levels and quotes to come from within 15 minutes prior to trade execution. Therefore, per trade profits cannot be computed for a few trades and we drop these trades from the computation of daily trade-size-weighted profits. Similarly, when assuming that trades are closed at the best bid or offer, we drop trades for which the side of the order book at which the trade would be closed is empty at trade execution.

[47] Trades can be closed at the prevailing best bid or offer provided that there is sufficient depth. We abstract from this issue when computing per trade profits because GFI data does not include the depth available at the best bid and offer.

[48] In the computation of fractions, trades are signed based on Markit intraday mid-quotes. A more robust approach is to consider only D2C trades for which, based on the latest order-book quote from within 15 minutes prior to trade execution, neither side of the order book is empty at trade execution and report the fraction of D2C trades with transaction prices that are strictly within the bid-offer spread. The corresponding fractions are 95.7% and 96.4% for CDX.IG and CDX.HY, respectively.

7 Conclusion

Using transaction data, we study the market structure and transaction costs of index CDSs after the implementation of the Dodd-Frank Act. The market structure is two-tiered and we identify dealer-to-client (D2C) trades and interdealer (D2D) trades. Transaction costs and price impacts are larger for D2C trades and increase with trade size, quoted bid-ask spread, and volatility. D2C trades Granger-cause D2D trades consistent with the interdealer market being used for managing inventory risk. Unique order-book data show that D2D transaction costs and price impacts vary across trading protocols with mid-market matching and workup attracting liquidity-motivated trades. D2C prices are typically better than those available on the main interdealer limit order book, suggesting that clients who value immediacy could not get better execution by trading in the interdealer market. This may partially justify the endurance of the two-tiered market structure.

Appendices

A Dodd-Frank Act Implementation Timeline

Jul 21, 2010	President Obama signs the Dodd-Frank Wall Street Reform and Consumer Protection Act (the "Dodd-Frank Act") into law.
Jan 9, 2012	The CFTC publishes the final rules for real-time public reporting of swap transaction data.
Nov 28, 2012	The CFTC announces mandatory central clearing of certain swaps in three implementation phases. In the first phase, swap dealers and private funds active in swap markets (so-called Category 1 Entities) are required to clear their swap trades. In the second phase, financial entities other than Category 3 Entities (so-called Category 2 Entities) are required to clear their swap trades. In the third phase, investment managers and pension plans (so-called Category 3 Entities) are required to clear their swap trades. End-users, i.e., non-financial entities hedging commercial risks, are exempt from mandatory central clearing.
Dec 31, 2012	Real-time public reporting of index CDS trades becomes mandatory for swap dealers.
Feb 28, 2014	Real-time public reporting of index CDS trades becomes mandatory for major swap market participants.
Mar 11, 2013	Central clearing becomes mandatory for Category 1 Entities trading CDX.IG or CDX.HY (for trades in the five-year contract tenor, mandatory central clearing applies to series 11 and all subsequent series).
Apr 10, 2013	Real-time public reporting of index CDS trades becomes mandatory for any swap market participant.
May 31, 2013	The CFTC publishes the final block-trade rules.[49]
Jun 4, 2013	The CFTC publishes the final rules for SEF compliance and mandatory trade execution on SEFs. These specify: (i) the (electronic) trading platforms that are required to be registered as SEFs and the prescribed methods of execution for trades in swaps that are subject to mandatory trade execution on SEFs (either execution against orders resting on a SEF's order book or execution against a response to a RFQ facilitated by a SEF and transmitted to at least three other SEF participants) and (ii) the process that SEFs can initiate (via so-called made available to trade determinations demonstrating sufficiently liquid trading) to get CFTC approval for mandatory trade execution of certain swaps on SEFs.[50]

[49] Block trades are exempt from the trade execution requirement and may be publicly disseminated with delay.
[50] Swaps eligible for made available to trade determinations have to be subject to mandatory central clearing.

Jun 10, 2013	Central clearing becomes mandatory for Category 2 Entities trading CDX.IG or CDX.HY.
Jul 30, 2013	Block trade rules become effective, with index CDS trades of notional amounts exceeding certain par-spread- and contract-tenor-dependent minimum block sizes being defined as block trades (note that minimum block sizes defining block trades do not necessarily coincide with the sizes at which publicly disseminated notional amounts are being capped).[51]
Aug 5, 2013	Closing date for applications to become a CFTC-registered SEF according to (i) from above. Temporarily registered SEFs are free to initiate made available to trade determinations that are subject to CFTC approval as set forth in (ii) from above.
Sep 9, 2013	Central clearing becomes mandatory for Category 3 Entities trading CDX.IG or CDX.HY.
Oct 2, 2013	The first temporarily registered SEFs start operating.
Jan 28, 2014	The CFTC approves a made available to trade determination for on-the-run and immediate off-the-run index CDSs on CDX.IG, CDX.HY, iTraxx Europe, and iTraxx Europe Crossover with five-year contract tenors.
Feb 26, 2014	The approved made available to trade determination becomes effective and all trades in the above-mentioned index CDSs (not qualifying as block trades or not being end-user exempt) must be executed on SEFs.

[51]Prior to July 30, 2013, all index CDS trades were publicly disseminated with delay and for trades of notional amounts exceeding USD 100 million, the disseminated notional amounts were capped at USD 100 million.

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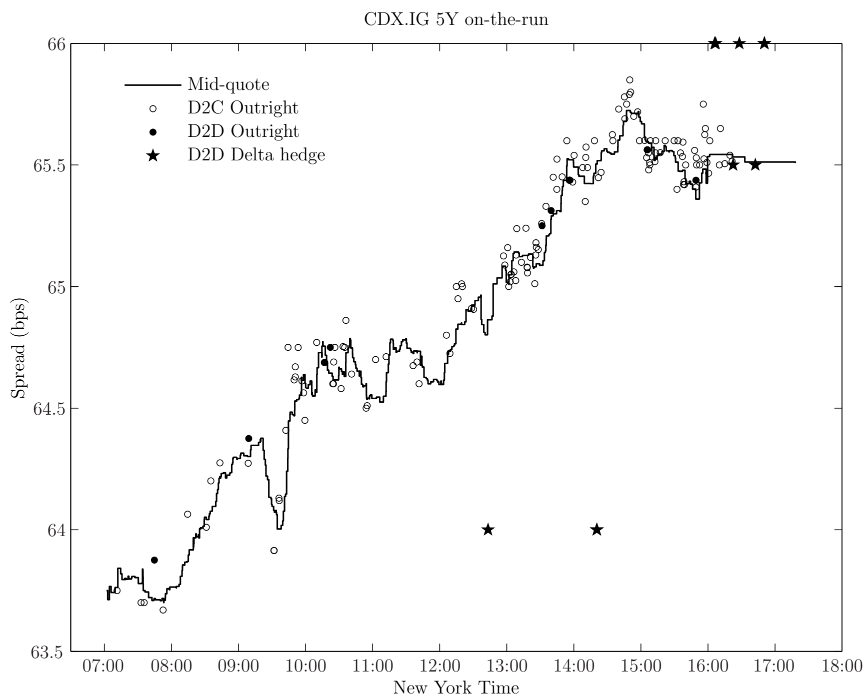

Figure 1: CDX.IG Trades and Quotes on May 6, 2015.

The figure shows transaction prices of all dealer-to-client (D2C) and dealer-to-dealer (D2D) trades in five-year on-the-run index CDSs on CDX.IG and the corresponding composite mid-quote on May 6, 2015. Circles indicate trades that are identified as being outright and stars indicate trades that are identified as being delta hedges of index swaptions. Unfilled symbols indicate D2C trades and filled symbols indicate D2D trades. Both transaction prices and quotes are in terms of par spreads and expressed in basis points (bps). Series 24 of CDX.IG was on-the-run on May 6, 2015.

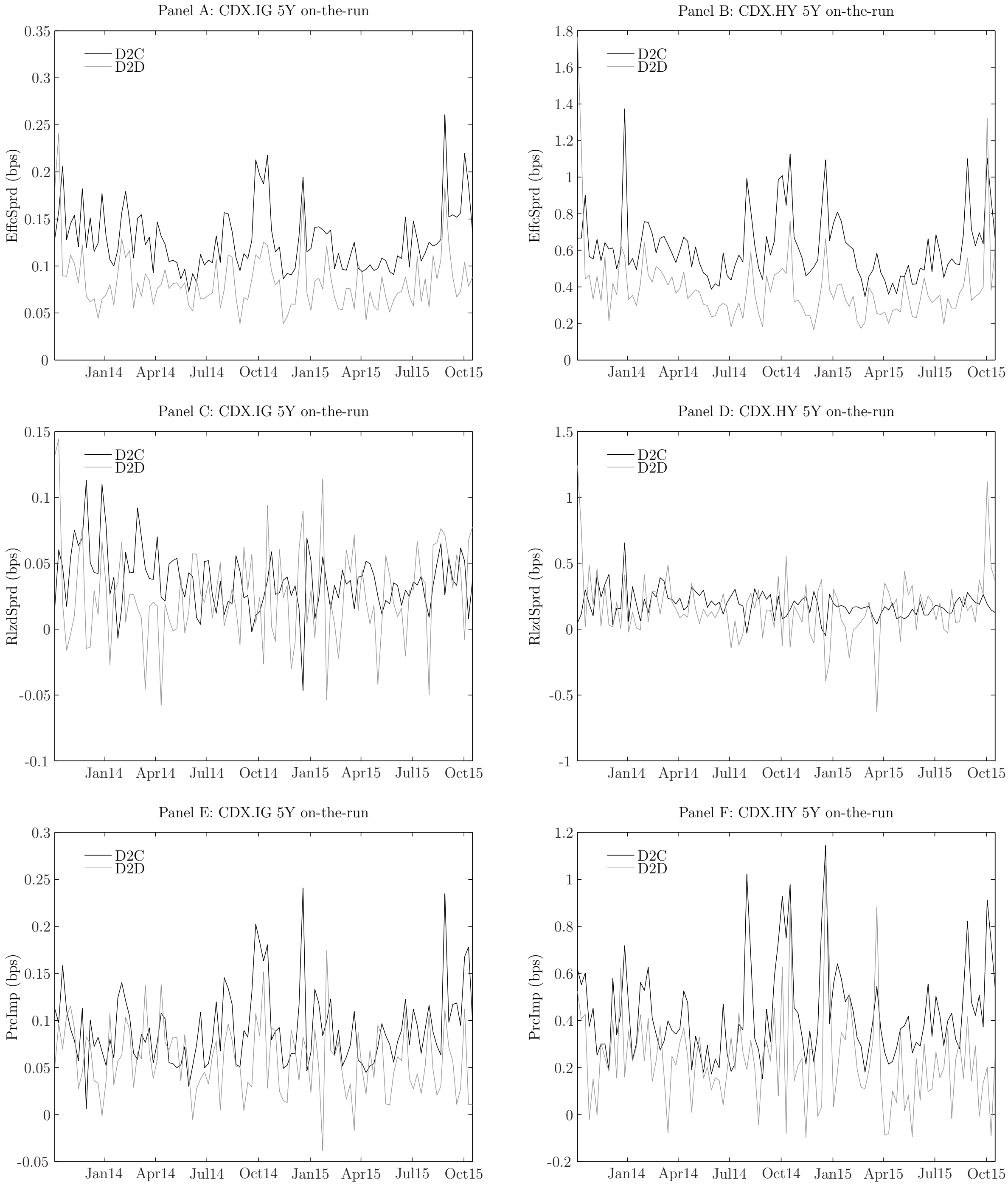

Figure 2: Weekly Average Effective Half-Spreads, Realized Half-Spreads, and Price Impacts. Panels A and B, Panels C and D, and Panels E and F, show weekly sample means of effective half-spreads (EffcSprd), realized half-spreads (RlzdSprd), and price impacts (PrcImp) of outright dealer-to-client (D2C) and dealer-to-dealer (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively. EffcSprd is defined as $q_t \times (p_t - m_t)$, where p_t is the transaction price and m_t is the latest mid-quote in the 15-minute period prior to trade execution. RlzdSprd is defined as $q_t \times (p_t - m_{t+\Delta})$, where $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. PrcImp is defined as $q_t \times (m_{t+\Delta} - m_t)$. Both transaction prices and quotes are in terms of par spreads and expressed in basis points (bps). Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm. The sample period is October 2, 2013 to October 16, 2015 and comprises 50,126 (8,881) and 71,697 (10,219) outright D2C (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively.

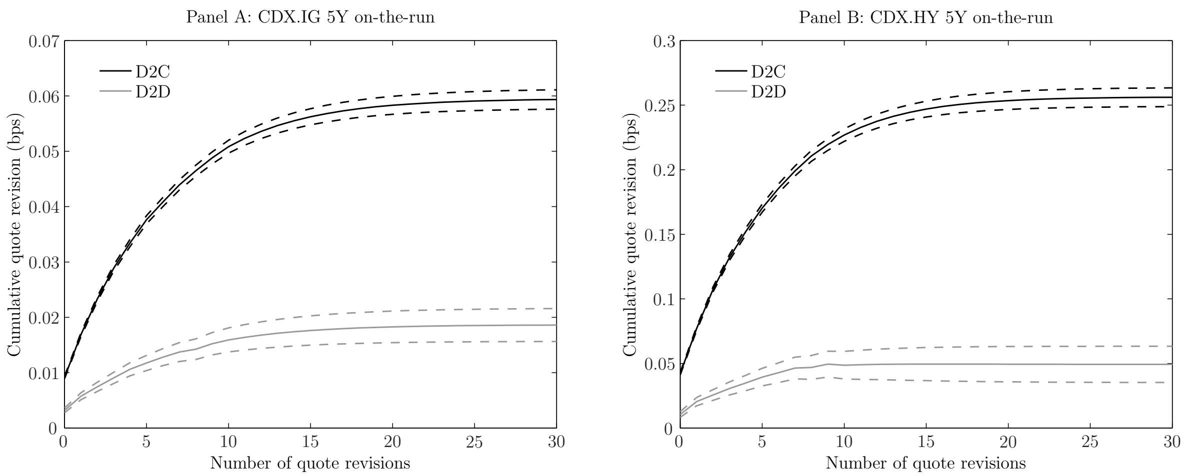

Figure 3: Price impact.

The panels show cumulative quote revisions in response to either a single protection-buyer-initiated dealer-to-client (D2C; solid black lines) trade or a single protection-buyer-initiated dealer-to-dealer (D2D; solid light gray lines) trade. The trades are outright five-year on-the-run index CDS trades in CDX.IG (Panel A) and CDX.HY (Panel B). Cumulative quote revisions are implied by event-time vector autoregressive models for mid-quote revisions, the sum of signed D2C trades that occur between quote revisions, and the sum of signed D2D trades that occur between quote revisions. Dashed lines mark 95% confidence intervals based on OLS standard errors. Quotes are in terms of par spreads and expressed in basis points (bps). The sample period is October 2, 2013 to October 16, 2015 and comprises 216,280 and 187,871 quote revisions for CDX.IG and CDX.HY, respectively.

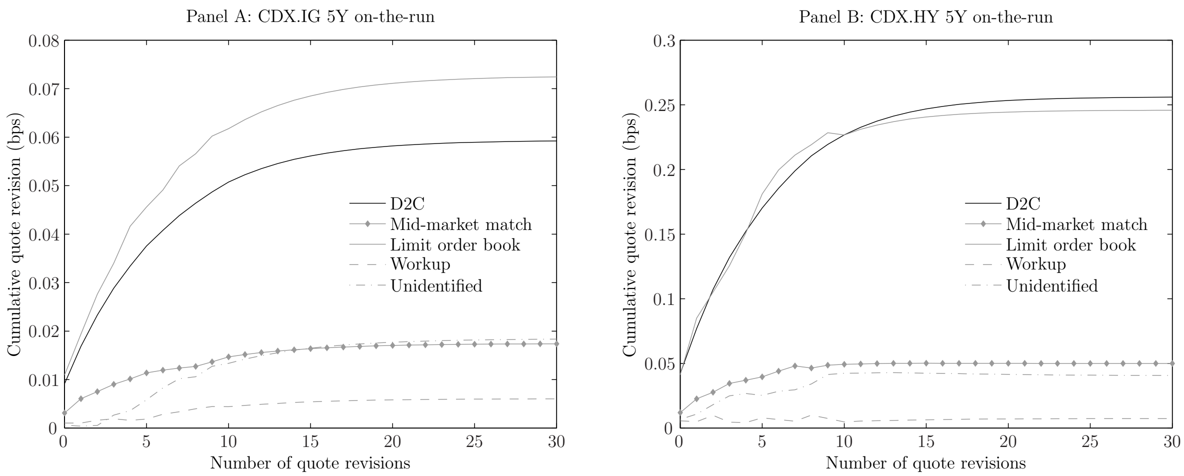

Figure 4: Price impact.

The panels show cumulative quote revisions in response to either a single protection-buyer-initiated dealer-to-client (D2C) trade (solid black lines) or a single protection-buyer-initiated dealer-to-dealer (D2D) mid-market match (marked solid light gray lines), limit-order-book trade (solid light gray lines), workup (dashed light gray lines), or trade with unidentified trading protocol (dash-dotted light gray lines). The trades are outright five-year on-the-run index CDS trades in CDX.IG (Panel A) and CDX.HY (Panel B). Cumulative quote revisions are implied by event-time vector autoregressive models for mid-quote revisions, the sum of signed D2C trades that occur between quote revisions, and sums of signed D2D mid-market matches, limit-order-book trades, workups, and trades with unidentified trading protocol that occur between quote revisions. D2D trades other than those that are executed on the GFI Swaps Exchange are ignored. Quotes are in terms of par spreads and expressed in basis points (bps). The sample period is October 2, 2013 to October 16, 2015 and comprises 216,280 and 187,871 quote revisions for CDX.IG and CDX.HY, respectively.

		USD MM		% of Trds						% of Vlm			
SEF	Trds	Sz	Vlm (ActVlm)	5Y	OTR	Bspk	Clrd	Blck	Cppd	Crv	Rll	Swptn	Trnch
Panel A1: CDX.IG *Dealer-To-Client*													
Bloomberg SEF	95	50	5,394 (7,681)	99.7	93.5	0.0	100.0	20.1	19.4	0.1	4.5	0.0	—
ICE Swap Trade	3	44	154 (318)	98.0	90.1	0.0	84.1	27.2	32.5	0.1	0.0	16.9	6.5
MarketAxess SEF	5	37	281 (533)	99.1	89.8	0.0	100.0	25.0	26.1	0.2	13.1	0.6	—
TW SEF	11	50	605 (1,310)	98.9	84.8	0.0	100.0	28.4	31.5	0.0	7.3	—	—
Total	114	50	6,433 (9,843)	99.6	92.4	0.0	99.6	21.3	21.2	0.1	5.0	0.4	0.2
Panel A2: CDX.IG *Dealer-To-Dealer*													
GFI Swaps Exchange	17	50	773 (808)	96.1	91.6	0.7	99.3	0.0	3.9	4.7	16.9	3.2	1.9
ICAP SEF	1	25	58 (71)	75.8	71.2	0.0	94.9	0.0	9.7	0.0	0.0	7.4	51.8
tpSEF	6	50	351 (445)	94.8	86.9	0.0	96.0	2.2	14.1	4.7	21.9	1.7	0.0
Tradition SEF	0	79	19 (30)	78.7	63.8	0.0	72.4	0.0	27.6	0.0	0.0	61.6	35.0
Total	24	50	1,201 (1,354)	94.8	89.3	0.5	98.0	0.5	6.8	4.4	17.3	3.9	4.3
Panel B1: CDX.HY *Dealer-To-Client*													
Bloomberg SEF	140	10	2,583 (2,840)	100.0	93.9	0.0	100.0	17.8	1.4	0.0	7.8	0.0	—
ICE Swap Trade	3	5	68 (77)	99.7	87.9	0.0	91.0	28.3	7.2	0.0	0.1	9.9	6.5
MarketAxess SEF	6	10	138 (150)	100.0	90.8	0.0	100.0	24.5	3.9	0.0	12.1	0.2	—
TW SEF	15	16	434 (639)	100.0	87.0	0.0	100.0	35.8	9.9	0.0	15.9	—	—
Total	164	10	3,224 (3,705)	100.0	93.0	0.0	99.8	19.9	2.3	0.0	8.9	0.2	0.1
Panel B2: CDX.HY *Dealer-To-Dealer*													
GFI Swaps Exchange	17	10	209 (211)	99.9	94.1	0.7	99.2	0.0	0.9	0.0	21.1	4.2	0.5
ICAP SEF	1	10	17 (25)	98.6	68.9	0.0	87.8	0.0	0.7	0.0	0.0	13.1	45.8
tpSEF	8	10	147 (157)	99.6	89.1	0.0	96.2	2.7	2.6	0.0	26.1	1.0	0.0
Tradition SEF	0	20	6 (8)	95.0	68.3	0.0	79.2	0.0	1.0	0.0	0.0	49.6	36.8
Total	27	10	380 (402)	99.7	91.5	0.4	97.8	0.9	1.4	0.0	21.7	4.1	3.0

Table 1: Descriptive Statistics of On-SEF Index CDS Trades.

The table shows descriptive statistics of on-SEF dealer-to-client (D2C) and dealer-to-dealer (D2D) index CDS trades in CDX.IG and CDX.HY by SEF. Trds is the number of trades per day computed as the total number of trades divided by the number of trading days in the sample period, 511. Sz is median trade size. Vlm is daily volume computed as the aggregate notional amount divided by the number of trading days in the sample period (ActVlm is actual daily volume computed equivalently using daily volumes reported by SEFs). 5Y (OTR) is the percentage of trades in five-year (on-the-run) index CDSs. Bspk is the percentage of trades with bespoke contract terms. Clrd is the percentage of cleared trades. Blck is the percentage of trades qualifying as block trades. Cppd is the percentage of trades that are disseminated with capped notional amounts. Crv (Rll) is the percentage of the aggregate notional amount that is identified as being part of curve trades (index rolls). Swptn (Trnch) is the percentage of the aggregate notional amount that is identified as being index swaption (index tranche swap) delta hedges. The sample period is October 2, 2013 to October 16, 2015 and comprises 58,222 (12,396) and 83,771 (13,585) D2C (D2D) trades in CDX.IG and CDX.HY, respectively.

	% of Trds		% of Vlm	
Trade Type	D2C	D2D	D2C	D2D
Panel A: CDX.IG				
Outright				
5Y on-the-run	90.0	79.9	88.5	67.2
Other	6.0	2.1	5.8	3.0
Package				
Roll 5Y on-the-run/immediate off-the-run	3.4	7.6	4.9	12.0
Other	0.6	10.4	0.8	17.8
Panel B: CDX.HY				
Outright				
5Y on-the-run	91.2	85.5	84.6	63.5
Other	5.3	3.5	6.1	7.7
Package				
Roll 5Y on-the-run/immediate off-the-run	3.2	6.4	8.8	18.2
Other	0.3	4.7	0.5	10.6

Table 2: Percentages of On-SEF Index CDS Trades and Volumes by Trade Type.

Panels A and B show percentages of on-SEF dealer-to-client (D2C) and dealer-to-dealer (D2D) index CDS trades and volumes in CDX.IG and CDX.HY, respectively, by trade type. The sample period is October 2, 2013 to October 16, 2015 and comprises 58,222 (12,396) and 83,771 (13,585) D2C (D2D) trades in CDX.IG and CDX.HY, respectively.

Trade Type	*Dealer-To-Client* Effc Sprd	Rlzd Sprd	Prc Imp	*Dealer-To-Dealer* Effc Sprd	Rlzd Sprd	Prc Imp	*D2C-D2D* Effc Sprd	Rlzd Sprd	Prc Imp
Panel A: CDX.IG									
Outright	0.137	0.031	0.106	0.088	0.025	0.063	0.049^{**}	0.006	0.043^{**}
Index roll	0.048	0.020	0.028	0.050	0.027	0.023	-0.002	-0.007	0.005
Panel B: CDX.HY									
Outright	0.674	0.166	0.508	0.402	0.155	0.246	0.273^{**}	0.011	0.262^{**}
Index roll	0.392	0.239	0.153	0.354	0.131	0.223	0.038	0.108^{*}	-0.070

Table 3: Effective Half-Spreads, Realized Half-Spreads, and Price Impacts by Trade Type. Panels A and B show sample means of effective half-spreads (EffcSprd), realized half-spreads (RlzdSprd), and price impacts (PrcImp) of dealer-to-client (D2C) and dealer-to-dealer (D2D) trades in CDX.IG and CDX.HY, respectively. Sample means are separately computed for outright trades in five-year on-the-run index CDSs and for index rolls between five-year on-the-run and immediate off-the-run index CDSs. EffcSprd is defined as $q_t \times (p_t - m_t)$, where p_t is the transaction price (the difference between on-the-run and immediate off-the-run transaction prices for index rolls) and m_t is the latest mid-quote (the difference between the latest on-the-run and immediate off-the-run mid-quotes for index rolls) in the 15-minute period prior to trade execution. RlzdSprd is defined as $q_t \times (p_t - m_{t+\Delta})$, where $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. PrcImp is defined as $q_t \times (m_{t+\Delta} - m_t)$. Both transaction prices and quotes are in terms of par spreads and expressed in basis points. Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm. ** and * denote rejection of a regression-based t test for the null hypothesis that D2C and D2D sample means are identical at the 1% and 5% level, respectively, with inference based on the Newey and West (1987) estimate of the covariance matrix of coefficient estimates. The sample period is October 2, 2013 to October 16, 2015 and comprises 50,126 (8,881) and 71,697 (10,219) outright D2C (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively and 943 (338) and 1,094 (329) D2C (D2D) index rolls between five-year on-the-run and immediate off-the-run index CDSs on CDX.IG and CDX.HY, respectively.

	Dealer-To-Client			*Dealer-To-Dealer*			*D2C-D2D*		
Trade Size	Effc Sprd	Rlzd Sprd	Prc Imp	Effc Sprd	Rlzd Sprd	Prc Imp	Effc Sprd	Rlzd Sprd	Prc Imp
Panel A: CDX.IG									
≤ 25	0.121	0.031	0.090	0.082	0.017	0.065	0.039**	0.015**	0.025**
25–50	0.131	0.022	0.109	0.095	0.022	0.073	0.036**	0.000	0.036**
50–100	0.143	0.022	0.121	0.090	0.053	0.037	0.053**	-0.031**	0.084**
> 100	0.169	0.051	0.118	0.125	0.153	-0.028	0.044**	-0.102**	0.146**
Panel B: CDX.HY									
≤ 5	0.603	0.169	0.434	0.383	0.108	0.275	0.220**	0.061	0.159**
5–10	0.636	0.120	0.516	0.413	0.154	0.259	0.223**	-0.034	0.257**
10–25	0.700	0.118	0.582	0.394	0.204	0.190	0.306**	-0.086*	0.392**
> 25	0.800	0.287	0.513	0.468	0.478	-0.011	0.332**	-0.191	0.523**

Table 4: Effective Half-Spreads, Realized Half-Spreads, and Price Impacts by Trade Size.
Panels A and B show sample means of effective half-spreads (EffcSprd), realized half-spreads (RlzdSprd), and price impacts (PrcImp) of outright dealer-to-client (D2C) and dealer-to-dealer (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively. Sample means are separately computed for quartiles of the trade size distribution. EffcSprd is defined as $q_t \times (p_t - m_t)$, where p_t is the transaction price and m_t is the latest mid-quote in the 15-minute period prior to trade execution. RlzdSprd is defined as $q_t \times (p_t - m_{t+\Delta})$, where $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. PrcImp is defined as $q_t \times (m_{t+\Delta} - m_t)$. Both transaction prices and quotes are in terms of par spreads and expressed in basis points. Trade size is in USD million. Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm. ** and * denote rejection of a regression-based t test for the null hypothesis that D2C and D2D sample means are identical at the 1% and 5% level, respectively, with inference based on the Newey and West (1987) estimate of the covariance matrix of coefficient estimates. The sample period is October 2, 2013 to October 16, 2015 and comprises 50,126 (8,881) and 71,697 (10,219) outright D2C (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively.

	CDX.IG			CDX.HY		
	EffcSprd	RlzdSprd	PrcImp	EffcSprd	RlzdSprd	PrcImp
D2C	0.121**	0.027**	0.093**	0.609**	0.154**	0.455**
	(67.10)	(11.84)	(29.95)	(74.40)	(13.63)	(30.27)
D2D	0.087**	0.021**	0.066**	0.390**	0.153**	0.236**
	(31.66)	(5.16)	(14.51)	(28.62)	(6.00)	(9.48)
MDM	0.008**	-0.007**	0.015**	0.014*	-0.040**	0.054**
	(5.45)	(-2.76)	(5.24)	(1.98)	(-3.40)	(4.51)
LRG	0.015**	-0.004	0.020**	0.062**	-0.041**	0.103**
	(8.39)	(-1.39)	(6.12)	(8.16)	(-3.36)	(7.65)
BLCK	0.044**	0.023**	0.020**	0.188**	0.122**	0.067**
	(17.70)	(6.33)	(4.84)	(19.72)	(7.13)	(3.91)
RFRNC	0.021**	0.023**	-0.002	0.111**	0.178**	-0.067**
	(8.20)	(4.98)	(-0.44)	(6.13)	(6.17)	(-2.61)
BAS	0.445**	0.034	0.410**	0.345**	0.069	0.276**
	(8.22)	(0.53)	(4.23)	(10.91)	(1.38)	(4.58)
SPRD/100	0.022	0.089*	-0.067	0.066*	0.015	0.051
	(0.61)	(2.05)	(-1.00)	(2.03)	(0.43)	(0.90)
VLTLTY	0.199**	-0.166**	0.365**	1.220**	-0.503*	1.722**
	(5.94)	(-3.83)	(5.72)	(7.34)	(-2.39)	(5.36)
N	59,007	59,007	59,007	81,916	81,916	81,916
D2C − D2D	0.033	0.006	0.027	0.219	0.001	0.218
p-value	<0.01	0.12	<0.01	<0.01	0.96	<0.01

Table 5: Regressions Controlling for Outright Trade Characteristics and Market Conditions. The table shows OLS estimates of regression specifications that control for selection bias in the comparison of effective half-spreads (EffcSprd), realized half-spreads (RlzdSprd), and price impacts (PrcImp) of outright dealer-to-client (D2C) and dealer-to-dealer (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY (t-statistics based on Newey and West (1987) standard errors are shown in parenthesis). EffcSprd is defined as $q_t \times (p_t - m_t)$, where p_t is the transaction price and m_t is the latest mid-quote in the 15-minute period prior to trade execution. RlzdSprd is defined as $q_t \times (p_t - m_{t+\Delta})$, where $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. PrcImp is defined as $q_t \times (m_{t+\Delta} - m_t)$. Both transaction prices and quotes are in terms of par spreads and expressed in basis points (bps). Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm. The explanatory variables include dummy variables for D2C trades (D2C), for D2D trades (D2D), for medium-sized trades (MDM; USD 25–50 MM for CDX.IG and USD 5–10 MM for CDX.HY), for large-sized trades (LRG; USD 50–100 MM for CDX.IG and USD 10–25 MM for CDX.HY), for block-sized trades (BLCK; +USD 100 MM for CDX.IG and +USD 25 MM for CDX.HY), and for trades with transaction prices at typical reference levels (RFRNC; par spread multiples 0.5 bps for CDX.IG and price multiples of 0.125% for CDX.HY), the bid-ask spread of the latest quote for the five-year on-the-run index CDS (BAS), the corresponding mid-quote (SPRD), and the implied volatility of three-month at-the-money swaptions on the five-year on-the-run index CDS (VLTLTY). Continuous explanatory variables are demeaned. The prior to last row shows the difference between D2C and D2D coefficient estimates and the last row shows the p-value of a Wald test for the null hypothesis that D2C and D2D coefficients are identical. ** and * denote statistical significance at the 1% and 5% level, respectively. The sample period is October 2, 2013 to October 16, 2015 and comprises 50,126 (8,881) and 71,697 (10,219) outright D2C (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively.

	CDX.IG			CDX.HY		
	EffcSprd	RlzdSprd	PrcImp	EffcSprd	RlzdSprd	PrcImp
D2C	0.047**	0.024**	0.023**	0.373**	0.224**	0.149**
	(13.11)	(5.97)	(6.31)	(16.52)	(8.12)	(5.52)
D2D	0.049**	0.028**	0.021**	0.360**	0.134**	0.226**
	(9.70)	(3.82)	(3.17)	(10.98)	(3.09)	(5.77)
BLCK	0.002	-0.007	0.009	0.022	0.017	0.004
	(0.47)	(-1.27)	(1.89)	(0.84)	(0.52)	(0.15)
BAS	0.356**	0.175*	0.181*	0.224**	0.223*	0.001
	(3.96)	(2.18)	(2.30)	(4.94)	(2.37)	(0.01)
SPRD/100	-0.062	-0.019	-0.043	-0.053	0.002	-0.055
	(-1.69)	(-0.58)	(-1.17)	(-1.33)	(0.04)	(-0.95)
VLTLTY	0.041	-0.061	0.102	0.632**	-0.127	0.759
	(0.68)	(-1.33)	(1.82)	(2.58)	(-0.29)	(1.47)
N	1,281	1,281	1,281	1,423	1,423	1,423
D2C − D2D	-0.002	-0.004	0.002	0.013	0.090	-0.077
p-value	0.72	0.61	0.79	0.65	0.02	0.06

Table 6: Regressions Controlling for Index Roll Characteristics and Market Conditions. The table shows OLS estimates of regression specifications that control for selection bias in the comparison of effective half-spreads (EffcSprd), realized half-spreads (RlzdSprd), and price impacts (PrcImp) of dealer-to-client (D2C) and dealer-to-dealer (D2D) index rolls between five-year on-the-run and immediate off-the-run index CDSs on CDX.IG and CDX.HY (t-statistics based on Newey and West (1987) standard errors are shown in parenthesis). EffcSprd is defined as $q_t \times (p_t - m_t)$, where p_t is the difference between on-the-run and immediate off-the-run transaction prices and m_t is the difference between the latest on-the-run and immediate off-the-run mid-quotes in the 15-minute period prior to trade execution. RlzdSprd is defined as $q_t \times (p_t - m_{t+\Delta})$, where $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. PrcImp is defined as $q_t \times (m_{t+\Delta} - m_t)$. Both transaction prices and quotes are in terms of par spreads and expressed in basis points (bps). Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm. The explanatory variables include dummy variables for D2C trades (D2C), for D2D trades (D2D), and for block-sized trades (BLCK; +USD 100 MM for CDX.IG and +USD 25 MM for CDX.HY), the bid-ask spread of the latest quote for the five-year on-the-run index CDS (BAS), the corresponding mid-quote (SPRD), and the implied volatility of three-month at-the-money swaptions on the five-year on-the-run index CDS (VLTLTY). Continuous explanatory variables are demeaned. The prior to last row shows the difference between D2C and D2D coefficient estimates and the last row shows the p-value of a Wald test for the null hypothesis that D2C and D2D coefficients are identical. ** and * denote statistical significance at the 1% and 5% level, respectively. The sample period is October 2, 2013 to October 16, 2015 and comprises 943 (338) and 1,094 (329) D2C (D2D) index rolls between five-year on-the-run and immediate off-the-run index CDSs on CDX.IG and CDX.HY, respectively.

Matching Trade Size	*Dealer-To-Client* Effc Sprd	*Dealer-To-Client* Rlzd Sprd	*Dealer-To-Client* Prc Imp	*Dealer-To-Dealer* Effc Sprd	*Dealer-To-Dealer* Rlzd Sprd	*Dealer-To-Dealer* Prc Imp	*D2C-D2D* Effc Sprd	*D2C-D2D* Rlzd Sprd	*D2C-D2D* Prc Imp
Panel A: CDX.IG									
$\leq$ 25	0.117	0.036	0.080	0.086	0.017	0.069	0.031**	0.019*	0.011
25–50	0.125	0.029	0.096	0.102	0.016	0.086	0.022**	0.013	0.010
50–100	0.124	0.010	0.114	0.099	0.055	0.044	0.025**	-0.045*	0.070**
$>$ 100	0.153	0.097	0.056	0.114	0.163	-0.049	0.039	-0.066	0.105**
Exact	0.124	0.026	0.098	0.097	0.019	0.078	0.027**	0.007	0.019*
Panel B: CDX.HY									
$\leq$ 5	0.575	0.154	0.420	0.384	0.071	0.313	0.191**	0.083	0.108*
5–10	0.580	0.117	0.464	0.448	0.179	0.269	0.132**	-0.063	0.195**
10–25	0.621	0.137	0.484	0.412	0.212	0.200	0.210**	-0.075	0.284**
$>$ 25	0.690	0.140	0.550	0.377	0.392	-0.016	0.313**	-0.253	0.566**
Exact	0.596	0.109	0.488	0.432	0.149	0.283	0.164**	-0.041	0.205**

Table 7: Effective Half-Spreads, Realized Half-Spreads, and Price Impacts of Matched Pairs. Panels A and B show sample means of effective half-spreads (EffcSprd), realized half-spreads (RlzdSprd), and price impacts (PrcImp) of matched pairs of outright dealer-to-client (D2C) and dealer-to-dealer (D2D) trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively. Sample means are separately computed for quartiles of the trade size distribution. EffcSprd is defined as $q_t \times (p_t - m_t)$, where p_t is the transaction price and m_t is the latest mid-quote in the 15-minute period prior to trade execution. RlzdSprd is defined as $q_t \times (p_t - m_{t+\Delta})$, where $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. PrcImp is defined as $q_t \times (m_{t+\Delta} - m_t)$. Both transaction prices and quotes are in terms of par spreads and expressed in basis points. Trade size is in USD million. Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm. A pair consists of a D2D trade and matching D2C trade in the same index CDS and with trade size in the same quartile of the trade size distribution (or with exactly matching trade size) that occur within a 15-minute window bracketing the execution of the D2D trade. In case of more than one matching D2C trade, the EffcSprd, RlzdSprd, and PrcImp of the D2C trade of the pair are averages of the matching D2C trades. ** and * denote rejection of a regression-based t test for the null hypothesis that the mean of the distribution of paired differences is zero at the 1% and 5% level, respectively, with inference based on the Newey and West (1987) estimate of the covariance matrix of coefficient estimates. The sample period is October 2, 2013 to October 16, 2015 and comprises 4,683 (3,372) and 6,463 (5,115) (exactly) matched pairs of outright D2C and D2D trades in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively.

	Coefficient Estimates					Granger Causality Tests		
	$\sum_{j=1}^{10} \Delta m_{t-j}$	x_t^{D2C}	$\sum_{j=1}^{10} x_{t-j}^{\text{D2C}}$	x_t^{D2D}	$\sum_{j=1}^{10} x_{t-j}^{\text{D2D}}$	Δm	x^{D2C}	x^{D2D}
Panel A1: CDX.IG								
Δm_t	0.344	0.009	0.017	0.003	0.005		4793.6	141.7
	(67.08)	(77.19)	(48.00)	(14.79)	(8.67)		[<0.01]	[<0.01]
x_t^{D2C}	2.069		0.239		0.022	1096.3		15.0
	(22.07)		(37.40)		(1.91)	[<0.01]		[0.13]
x_t^{D2D}	-0.172	0.023	0.030		0.137	27.2	102.4	
	(-3.37)	(19.87)	(8.67)		(21.96)	[<0.01]	[<0.01]	
Panel A2: CDX.HY								
Δm_t	0.254	0.042	0.074	0.011	0.020		5351.7	84.5
	(42.61)	(81.68)	(49.49)	(9.48)	(6.07)		[<0.01]	[<0.01]
x_t^{D2C}	0.410		0.322		-0.007	851.6		11.7
	(15.28)		(48.10)		(-0.49)	[<0.01]		[0.31]
x_t^{D2D}	-0.071	0.023	0.027		0.131	49.3	119.7	
	(-5.70)	(21.21)	(8.59)		(19.49)	[<0.01]	[<0.01]	

Panel B: Price Impact

	CDX.IG			CDX.HY		
	D2C	D2D	D2C − D2D	D2C	D2D	D2C − D2D
Λ	0.060	0.019	0.041	0.256	0.049	0.207
	(65.51)	(12.24)	(23.53)	(68.47)	(6.87)	(25.80)

Panel C: Price Discovery

	CDX.IG			CDX.HY		
	D2C	D2D	Trade-Unrelated	D2C	D2D	Trade-Unrelated
R^2	28.61	0.83	70.56	37.73	0.30	61.97

Table 8: VAR Estimates.

The table shows coefficient estimates of event-time vector autoregressive (VAR) models for mid-quote revisions (Δm), the sum of signed dealer-to-client (D2C) trades that occur between quote revisions (x^{D2C}), and the sum of signed dealer-to-dealer (D2D) trades that occur between quote revisions (x^{D2D}). Panels A1 and A2 show VAR coefficient estimates (t-statistics based on OLS standard errors are shown in parenthesis) and Wald test statistics (p-values are shown in brackets) for the null hypothesis that the column variable does not Granger-cause the row variable. Coefficient estimates of contemporaneous variables are separated from coefficient estimates of lagged variables and sums of the latter are reported in columns that show sums of lagged variables. Panel B shows price impact estimates (Λ; t-statistics based on OLS standard errors are shown in parenthesis) as captured by the model-implied long-run cumulative quote revision (in basis points) in response to either a single protection-buyer-initiated D2C trade or a single protection-buyer-initiated D2D trade, as well as the difference in price impacts of D2C and D2D trades. Panel C shows a model-implied variance decomposition of efficient price innovations into trade-related and trade-unrelated components (in percent of the variance of efficient price innovations). Quotes are in terms of par spreads and trade direction used to sign trades is inferred by the Lee and Ready (1991) algorithm. The sample period is October 2, 2013 to October 16, 2015 and comprises 216,280 and 187,871 quote revisions for CDX.IG and CDX.HY, respectively.

	Mid-Market Matching	Limit Order Book	Workup	Unidentified Protocol
Panel A: CDX.IG				
Outright				
5Y on-the-run	52.2	19.2	19.9	8.8
Other	13.6	8.8	18.4	59.1
Package				
Roll 5Y on-the-run/immediate off-the-run	20.1	17.2	27.9	34.8
Other	7.9	23.7	27.2	41.1
Total	42.6	19.4	21.6	16.4
Panel B: CDX.HY				
Outright				
5Y on-the-run	58.6	15.8	15.6	10.0
Other	6.5	7.3	14.9	71.3
Package				
Roll 5Y on-the-run/immediate off-the-run	31.2	19.2	16.1	33.6
Other	5.1	24.1	28.4	42.4
Total	49.3	16.5	16.2	18.0

Table 9: GFI Swaps Exchange Volume Shares by Trading Protocol.

Panels A and B show percentages of GFI Swaps Exchange trading volumes of index CDS trades in CDX.IG and CDX.HY, respectively, by trading protocol. Row values add to 100% and delta hedges of index swaption and tranche swap trades are excluded from the computation. The sample period is October 2, 2013 to October 16, 2015 and comprises 8,253 and 8,199 (non-delta-hedge) trades for CDX.IG and CDX.HY, respectively.

	CDX.IG			CDX.HY		
	EffcSprd	RlzdSprd	PrcImp	EffcSprd	RlzdSprd	PrcImp
CONST	0.102**	-0.014*	0.116**	0.479**	-0.049	0.528**
	(30.09)	(-1.99)	(15.56)	(12.80)	(-0.84)	(9.79)
MTCH	-0.041**	0.004	-0.045**	-0.155**	0.014	-0.168**
	(-9.94)	(0.59)	(-5.83)	(-5.08)	(0.26)	(-3.42)
WRKUP	0.004	0.003	0.001	0.011	-0.020	0.030
	(0.95)	(0.35)	(0.15)	(0.55)	(-0.50)	(0.79)
UNID	0.039*	0.098**	-0.059**	0.351*	0.581**	-0.230**
	(2.00)	(3.38)	(-3.55)	(2.11)	(3.26)	(-3.34)
MDM	0.010**	0.008	0.002	0.001	0.050	-0.048
	(3.20)	(1.32)	(0.25)	(0.05)	(1.13)	(-1.25)
LRG	0.007	0.019	-0.012	0.002	0.033	-0.030
	(1.11)	(1.95)	(-1.25)	(0.10)	(0.66)	(-0.60)
BLCK	-0.001	0.063*	-0.064**	-0.025	0.346	-0.371*
	(-0.08)	(2.23)	(-2.73)	(-0.34)	(1.95)	(-2.43)
RFRNC	0.015**	0.003	0.012	0.060	0.092	-0.032
	(2.90)	(0.22)	(1.02)	(1.33)	(1.29)	(-0.54)
BAS	0.312**	0.151	0.161	0.216**	0.079	0.137
	(4.24)	(1.50)	(1.21)	(4.96)	(0.87)	(1.51)
SPRD/100	0.119	-0.020	0.140	0.306	0.378	-0.072
	(1.95)	(-0.19)	(1.95)	(1.63)	(1.73)	(-0.78)
VLTLTY	0.139**	-0.017	0.156	0.485	-1.346*	1.831**
	(3.22)	(-0.20)	(1.58)	(1.43)	(-1.98)	(2.97)
N	6,623	6,623	6,623	6,844	6,844	6,844

Table 10: Regressions Controlling for D2D Trade Characteristics and Market Conditions. The table shows OLS estimates of regression specifications that control for selection bias in the comparison of effective half-spreads (EffcSprd), realized half-spreads (RlzdSprd), and price impacts (PrcImp) of order-book trades, mid-market matches, workups, and trades with unidentified trading protocol in five-year on-the-run index CDSs on CDX.IG and CDX.HY (t-statistics based on Newey and West (1987) standard errors are shown in parenthesis). EffcSprd is defined as $q_t \times (p_t - m_t)$, where p_t is the transaction price and m_t is the latest mid-quote in the 15-minute period prior to trade execution. RlzdSprd is defined as $q_t \times (p_t - m_{t+\Delta})$, where $m_{t+\Delta}$ is the first mid-quote in the 15-minute period that follows trade execution by 15 minutes. PrcImp is defined as $q_t \times (m_{t+\Delta} - m_t)$. Both transaction prices and quotes are in terms of par spreads and expressed in basis points (bps). Trade direction, q_t, is inferred by the Lee and Ready (1991) algorithm. The explanatory variables include a constant (CONST), dummy variables for mid-market matches (MTCH), for workups (WRKUP), for trades with unidentified trading protocol (UNID), for medium-sized trades (MDM; USD 25–50 MM for CDX.IG and USD 5–10 MM for CDX.HY), for large-sized trades (LRG; USD 50–100 MM for CDX.IG and USD 10–25 MM for CDX.HY), for block-sized trades (BLCK; +USD 100 MM for CDX.IG and +USD 25 MM for CDX.HY), and for trades with transaction prices at typical reference levels (RFRNC; par spread multiples 0.5 bps for CDX.IG and price multiples of 0.125% for CDX.HY), the bid-ask spread of the latest Markit intraday quote for the five-year on-the-run index CDS (BAS), the corresponding mid-quote (SPRD), and the implied volatility of three-month at-the-money swaptions on the five-year on-the-run index CDS (VLTLTY). Continuous explanatory variables are demeaned. ** and * denote statistical significance at the 1% and 5% level, respectively. The sample period is October 2, 2013 to October 16, 2015 and comprises 1,280 (3,640) [1,243] {460} and 1,050 (4,261) [1,084] {449} outright limit-order-book trades (mid-market matches) [workups] {trades with unidentified trading protocol} in five-year on-the-run index CDSs on CDX.IG and CDX.HY, respectively.