Intermediation Networks and Market Liquidity: Evidence from CDS Markets[†]

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Abstract

Theory predicts that intermediation networks affect the liquidity of markets. Using supervisory data between 2010-16 for the over-the-counter credit default swap market, we empirically test several predictions and evaluate how changes in intermediation networks are related to the liquidity of dealers and the market. We find that a market's network relates to the liquidity provision of dealers, both individually and collectively, as seen through trade volumes, market participation, and inventory management. Further, we find execution costs and bid-ask spreads are impacted by intermediation trade, though the effects of interconnectedness among dealers with clients differs from those among dealers with one another.

Keywords: credit default swaps, dealers, intermediation costs, liquidity, OTC trading networks
JEL Classification Numbers: D40, G12, G28, L14

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Over-the-counter (OTC) markets rely on dealers to intermediate trade and provide liquidity through both holding and managing asset inventories. To maintain these services, dealers form intermediation trade networks with clients and other dealers to offset excess inventories. Several theoretical models have examined how intermediaries manage their inventory risk (Ho and Stoll (1983); Viswanathan and Wang (2004); Duffie et al. (2005)) and the role that intermediation networks play (Gofman (2011); Babus and Kondor (2018); Neklyudov (2019)).

These works have highlighted how intermediation relationships reflect a positive channel for influencing liquidity by providing dealers with trading opportunities and easing the difficulty of rebalancing portfolios. However, changes to intermediation networks which reduce relationship density, due to an increase in inventory costs that results in dealers minding inventories more tightly and limiting who they trade with (Hugonnier et al. (2020)), or simply eliminate trading relationship (Elliott (2015)), can decrease market liquidity.[1] While the direct consequences of an individual's network have been emphasized (Di Maggio et al. (2017); Hollifield et al. (2017); Li and Schürhoff (2019)), little empirical work has explored the broader implications that indirect relationships have on liquidity.

In this paper, we empirically examine several hypotheses of the theoretical literature linking the density of intermediation networks to the liquidity in OTC markets. Unlike the previous empirical studies that have focused on individual market participants, we consider intermediation networks at both the individual participant-level and at the market-level. In addition, we separate the network effects along with the two-tiered structure of trade; i.e., trades between dealers and clients (dealer-to-client), and trades between dealers (interdealer).

We investigate the relationship of intermediation networks and liquidity for the case of the U.S. markets for single-name credit default swaps (CDS).[2] We employ a rich supervisory dataset of CDS transactions and positions between 2010 and 2016 to evaluate the market's intermediation. This period offers rich variation, as CDS markets saw new regulations enacted to limit the risk

[1] An example studied in the literature is the exit of Drexel Burnham Lambert from the junk bond market in 1990. It was shown that the exit influenced both the volume of trade and the price of assets (Brewer and Jackson (2000)). Other examples include the impact of financial innovations on risk-sharing; e.g., the introduction of reinsurance that allowed insurance companies to more easily share risks, and the securitization of mortgages that allowed broader sharing of real estate risk. In both cases, the volume of trading increased.

[2] A credit default swap is a contract that ensures an underlying bond, or a basket of bonds, against losses due to default.

of large bank-dealer institutions.[3] With these data, we reconstruct the intermediation network of market participants across hundreds of assets. Over the sample period, we find a series of significant changes to intermediation networks due to dealer participation and network density declining and the manner in which dealers manage inventories. These changes provide ampule variation to investigate the question of how intermediation networks influence liquidity provision.

We characterize the density of intermediation networks by constructing measures that capture the trade relationship sets of the dealer-to-client and interdealer segments at the level of individual dealers and the collective market. Specifically, we consider the *completeness* of these networks, which we define as the ratio of the number of relationships in each network over the number of relations in a complete network, where every participant is connected to every other participant. We use these network density measures to study several expressions of market liquidity: (i) transaction volume, (ii) the inventory held by individual dealers and the aggregate dealer community, (iii) execution costs, and (iv) bid-ask spreads.

Motivated by the theoretical literature, we formulate several hypotheses on how the completeness of intermediation networks can be used to explain aspects of market liquidity. First, we consider whether increased completeness allows markets to function more efficiently, by allowing for more transactions, measured by the notional volume of CDS contracts traded. We find a significant and positive relationship between completeness and increased client volume for both the interdealer and dealer-to-client market networks. An increase in the completeness of the interdealer market network by 10 percent is associated with an increase of 7-8 percent in dealer-to-client volumes. The effect is larger for the dealer-to-client market network where an increase of completeness by 10 percent is associated with an increase in dealer-to-client volume by 26-37 percent.

Beyond market volume, we also consider how network completeness relates to measures of risk-bearing capacity for dealers, both individually and on aggregate. We measure risk-bearing capacity through both the number of dealers and the size of dealer inventories. The literature suggests that the difficulty to offset inventory, measured by market completeness, plays a role in the demand

[3] Following the 2007-09 financial crisis, the Basel 2.5 and Basel III accords were implemented, and the United States Congress passed the Dodd-Frank Wall Street Reform and Consumer Protection Act (Dodd-Frank Act), a wide-ranging reform of regulations for institutions and markets. Included among the reforms is a mandate that standardized swap contracts be centrally cleared; the Volcker rule, which places limits on dealer activity; increased margin requirements for bilateral transactions relative to centrally cleared ones; and increased capital requirements for bank-affiliated dealers.

for additional dealer balance sheets (Carapella and Monnet (2020)). We study this relationship and find that an increase in the completeness of the interdealer network at the market-level by 10 percent is associated with a decrease in the number of dealers by 0.9-1.0, while a 10 percent increase in the completeness of the dealer-to-client network at the market-level is associated with a decrease in the number of dealers by 0.8-2.5. These results are consistent with more complete networks being more efficient and with being able to achieve the same level of intermediation with a smaller number of dealers.

The literature on intermediation networks and the ability of dealers to mitigate inventory risk predicts a positive relationship between both the completeness of dealer and market networks, and the size of a dealer's inventory: counterparty relationships provide dealers with mechanisms to manage inventory risk, and more complete networks allow for bigger inventories to be liquidated quickly, if necessary (Wang (2018); Yang and Zeng (2019)). We test these predictions empirically and confirm the theoretical predictions that increased completeness of either, or both, the interdealer and dealer-to-client networks at the individual dealer-level are associated with higher dealer inventory levels.

While the literature has mostly focused on networks of individual dealers, our data allow us to consider market-wide networks and explore whether the positive relationship that holds at the individual dealer-level between network completeness and dealer inventory also holds at the market-level. We find that, unconditionally, higher levels of completeness at the market-level are associated with higher inventory levels. However, when we account for the completeness of individual dealer networks, we find the opposite: higher levels of completeness at the market-level are associated with lower individual dealer inventory levels. These results may potentially be explained by dealers with more complete individual networks being able to have large intermediation capacity, reflected in higher inventories, while more complete markets are able to more efficiently allocate inventory to clients, reducing individual dealer inventories.

Beyond dealer and market inventory, completeness of intermediation networks can also affect the cost of transacting in a market. The theoretical literature predicts that the cost of transacting is inversely related to the degree of completeness of the network of an individual dealer (Babus and Kondor (2018)). Similar to previous studies of the ABS, CDO, CMBS, and Non-Agency CMO markets by Hollifield et al. (2017), and the corporate bond market by Di Maggio et al. (2017), we find this prediction to hold true in the single-name CDS markets. However, in contrast to other papers, we are able to focus separately on the relationship between network completeness for different networks and different levels and the cost of transacting. We find that a dealer's execution cost in transacting with other dealers declines as the completeness of the dealer's individual dealer-to-client network increases, but that this execution cost is not related to the completeness of the network of this individual dealer with other dealers. On the other hand, bid-ask spreads between dealers and clients decline when the completeness of an individual dealer's network with other dealers increases, though the interdealer bid-ask spread is not related to the completeness of the individual dealer's network with other dealers. These results are consistent with dealer execution costs being driven largely by a dealer's transactions with clients – and any imbalances they may create to dealer inventories – while the bid-ask spreads are primarily driven by the ability of the dealer to offload inventory with other dealers, but not necessarily other clients.

When considering the completeness of the intermediation network for the market – rather than for individual dealers – we find somewhat different results. While the theoretical literature, e.g., Babus and Kondor (2018), suggests that more complete market networks are associated with lower execution costs and bid-ask spreads, we find that this is not always the case. In particular, we find that a dealer's execution cost when trading with other dealers increases, as the completeness of the dealer-to-client network at the market-level increases. This finding highlights how interdealer trade relies on the demand to intermediate inventory. As the dealer-to-client network becomes more complete, a dealer's need to intermediate inventory within the interdealer network declines, such that dealers charge higher execution costs to one another.

Our paper contributes to several separate strands of literature. First, we validate several predictions in the literature regarding the relationship between market structure and dealer behavior in an over-the-counter market. Second, we document inventory management and pricing practices by dealers in the single-name CDS markets. Finally, we also highlight how regulatory reforms can impact trade intermediation networks and study the connection to market liquidity.

The early literature on market microstructure addresses how inventory is managed by monopolistic dealers. Garman (1976), Stoll (1978), Amihud and Mendelson (1980), and Ho and Stoll (1983) propose models of dealer inventories and market microstructure. Reiss and Werner (1998) and Hansch et al. (1998) use data from the London Stock Exchange – a centralized exchange –

and find empirical support for the theoretical predictions. In the case of markets with competing dealers, Ho and Stoll (1983) show that if clients can costlessly transact with multiple dealers, dealers respond by adjusting their bid-ask spreads to attract client trades that reduce the dealers' inventories. In such models, all volume is concentrated between dealers and clients, and dealers avoid trading with other dealers. To explain the large interdealer volume it becomes necessary to introduce frictions. Wang (2018) and Yang and Zeng (2019) introduce networks where trade is only possible among connected parties and describe how core-periphery networks arise endogenously in over-the-counter markets. We empirically test several hypotheses derived from their papers by examining how intermediation network completeness relates to trading volume, inventories, and price.

The market structure of CDS markets and the liquidity of the CDS market has been examined in several studies. Shachar (2012) examines the determinants of liquidity provision by dealers in the CDS market and finds that order imbalances of end-users cause significant price impact, and that dealer inventories influence dealer willingness to intermediate. Siriwardane (2019) investigates how capital shocks to CDS dealers can impact pricing in the CDS market and finds that dealer balance sheet constraints and market segmentation frictions lead to CDS bid-ask spreads widening. Du et al. (2016) considers the effect of counterparty risk on trading, where the risk that a party to a CDS transaction might default at the time that the reference entity also defaults. They find that while counterparty risk has only a modest impact on the pricing of CDS contracts, it has a large impact on the choice of counterparties.

Collin-Dufresne et al. (2020) study the differences in index CDS traded on swap exchange facilities between dealer-to-client and dealer-to-dealer transactions. They find evidence that dealer-to-client transactions have a higher average price impact than dealer-to-dealer transactions and that they Granger-cause dealer-to-dealer transactions, consistent with the interdealer market being used to manage inventory risk. Riggs et al. (2020) specifically focuses on the consequences of the centralization of trade of the dealer-to-client trade of index CDS and how clients search for liquidity. They find that customer-dealer relationships are important empirical determinants of customers' choice of trading mechanism and dealers' liquidity provision.

D'Errico et al. (2018) consider the network of counterparties in the CDS market and show that it consists of dealers, risk sellers such as hedge funds, and risk buyers such as asset managers, with risk ending up in a few leading risk buyers with portfolios that show large exposures to potentially correlated reference entities.Eisfeldt et al. (2018) calibrate a counterparty risk network model for the CDS market and study the impact of a potential exit of a key intermediary. Our paper studies the evolution of CDS markets and studies the relationship between intermediation networks and measures of market liquidity.

The remainder of the paper is organized as follows. In Section 1 we provide an overview of the single-name CDS market, describe the data used in our study, and how intermediation behavior changed over the sample period. Section 2 provides an overview of OTC market intermediation networks, introduces our network completeness measures, and summary statistics on how CDS intermediation network evolved over the period we study. Section 3 discusses the theoretical hypotheses we test connecting intermediation network density and market liquidity. In Section 4 we empirically test the hypotheses and present our findings. We conclude in Section 5.

1 The Single-name CDS Market

A single-name credit default swap (CDS) insures against losses on a bond of a corporate issuer, following the issuer's default. If the corporate issuer of the bond does not default before the maturity of the contract, the CDS contract expires worthless.[4] In the case of default, the seller of CDS protection pays the difference between the bond's face value and default auction value, to the purchaser. Single-name CDS contracts are traded through an over-the-counter market with a core-periphery microstructure of trade. A small number of dealers intermediate trade among themselves and with a larger number of clients on the periphery (Siriwardane (2019)). Dealers intermediate credit risk by buying and selling CDS contracts, either as a service to clients or to hedge internal corporate bond holdings and risks. On the other hand, clients who include depository institutions, insurance companies, and investment companies, such as hedge funds and investment funds, trade CDS contracts to hedge exposure to the default of a corporation; to speculate on potential default, or to synthetically create corporate bond positions.

[4] There are several additional features of single-name CDS contracts. For example, many CDS contracts include a coupon, paid by the buyer to the seller, as long as the underlying corporation is not in default.

1.1 Data

Our data include every CDS transaction on which the reference entity is a U.S.-domiciled corporation, as well as the weekly positions of every participant in this market. Having access to every transaction and weekly positions of every participant allows us to construct networks between market participants, including networks between dealers and between dealers and clients.

The CDS transaction and position data are provided by the Depository Trust & Clearing Corporation (DTCC).[5] DTCC provides trade processing services for most major dealers in CDS markets. After a trade is registered with DTCC, it is recorded into the Trade Information Warehouse (TIW). The part of the TIW that we have access to includes information on all standardized and confirmed CDS transactions involving U.S. entities since 2010, where the transactions involve a U.S. counterparty or a U.S. reference entity. The data also include weekly information on outstanding positions between counterparties. Reported positions represent the accumulation of all past reported transactions between the counterparties. All counterparties are identified in the data set. Approximately 10 percent of transactions include the credit spread at which the transaction took place. The total number of reference entities with senior-tier debt is 1032, while the total number of dealers is 32. In addition, we collect information on the volume of index CDS contracts that we use as controls in our models.

We enhance the information in the TIW dataset, with data from Markit Group Ltd. that capture market-wide CDS price information. Markit provides CDS spreads for a variety of maturities and seniorities of the referenced underlying corporate bonds. Additionally, Markit provides base currencies and the International Swap Dealer Association (ISDA) default documentation clauses. We use the most liquid maturity of five years, senior reference obligations, U.S. dollar-denominated contracts, and average overall ISDA default documentation clauses. We use expected default recovery rates reported by Markit for each reference entity and each corporate bond underlying the contract. In addition, we use the Markit dataset to implicitly determine the date that CDS contracts on a reference entity become eligible for central clearing: we set the date to the first time we either observe a transaction between a dealer and the central counterparty on the reference entity or when the reference entity becomes part of a CDS index.

[5]The CDS data in this paper are confidential in nature and are provided to the Office of Financial Research (OFR) by The Depository Trust & Clearing Corporation.

In cases where the DTCC dataset provides information on the spread for a specific CDS transaction or an upfront payment, we estimate the transaction spread. By comparing the transaction spread to the Markit credit spread, one can determine whether the buyer or the seller initiates the transaction. If the transaction spread is above the Markit spread, we assume that the buyer initiated the transaction. If it is below, we assume that the seller initiated the transaction. That is, we consider the difference between the Markit credit spread and the DTCC transaction spread to represent the bid-ask spread for the specific transaction.[6] In addition, we determine whether a transaction is dealer- or client-initiated, based on which side paid the implied bid-ask spread.[7]

Finally, in addition to the TIW and Markit datasets, we use the Financial Industry Regulatory Authority's regulatory Trade Reporting and Compliance Engine (TRACE) dataset that includes information on corporate bond transactions. Unlike the TIW dataset, not all counterparties are identified in this dataset. We use TRACE to map CDS contracts to the underlying corporate bonds and to calculate the volume of trading for the underlying corporate bond.

1.2 CDS Market Statistics

The credit default swaps (CDS) markets developed in the early 1990s and grew substantially in the run-up to the 2007-09 Financial Crisis. As a result of the crisis and the role CDS played in the crisis, several regulatory reforms were enacted during the time of our study 2010-2016. Table 1 presents summary statistics for the single-name CDS market during this period, with variables averaged at monthly aggregations and split by year. We note that the average number of dealers and average dealer gross notional per reference entity declined during the period. While the average number of clients and the number of client trades per reference entity changed relatively little, the average monthly volume between clients and dealers declined. The biggest decline occurred in the average monthly market volume, which dropped by more than 90 percent, mostly due to the decline in the average monthly volume in interdealer trades, which dropped by more than 95 percent. Consistent with the decline in the number of dealers, the number of clients per dealer

[6] In the case where an upfront payment is reported, we use the R implementation of ISDA's conventional model to convert the upfront fee to a par spread. The same methodology is used in Iercosan and Jiron (2017). Similar to our use of the Markit credit spread to calculate the bid-ask spread of a specific transaction, Iercosan and Jiron (2017) defines the execution cost of a transaction using the CDS par spread relative to the end-of-day CDS consensus par spread from Markit.

[7] Our definition of bid-ask spread corresponds to half of the round-trip cost of buying and selling the same contract.

increased. Consistent with the decline in the volume between dealers, the number of interdealer counterparties for each dealer has declined. Finally, the number of dealers each client trades with remained stable, and the number of clients each dealer trades with increased.

Table 1: Monthly CDS Market Statistics per Single-name Reference Entity

Year:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Volume	2,350.6	935.5	639.0	463.2	372.1	192.6	134.9
	(1886.9)	(5878.0)	(1380.9)	(927.9)	(701.4)	(316.3)	(305.9)
Interdealer Volume	2,262.3	770.5	530.6	373.4	282.9	127.4	72.1
	(1885.4)	(1761.5)	(1267.2)	(826.5)	(605.6)	(264.3)	(270.6)
Client Volume	88.2	165.0	108.4	89.8	89.2	65.2	62.8
	(18.8)	(5585.8)	(227.3)	(179.2)	(174.6)	(108.8)	(103.6)
# of Trades	177.2	140.2	106.6	81.1	69.1	42.0	38.9
	(28.9)	(213.3)	(161.5)	(122.2)	(106.0)	(58.5)	(50.0)
# of Interdealer Trades	160.4	122.0	82.6	59.7	47.4	22.7	14.0
	(27.3)	(199.9)	(138.1)	(90.5)	(71.2)	(30.0)	(28.3)
# of Client Trades	16.8	18.2	24.0	21.4	21.8	19.3	25.0
	(2.8)	(32.9)	(45.6)	(47.3)	(50.1)	(42.2)	(36.4)
Dealer Net Notional	-17.5	-32.5	-20.8	-20.4	-24.9	-42.7	-35.4
	(20.5)	(263.7)	(243.6)	(195.2)	(180.0)	(133.7)	(101.1)
Dealer Gross Notional	7,151.0	7,510.8	7,003.4	5,210.8	3,649.6	2,716.0	1,962.4
	(974.6)	(9407.0)	(9369.0)	(7181.4)	(5267.3)	(3847.9)	(2946.4)

Note: The table presents summary statistics for the volume, number of trades, and dealer inventories per reference entity, averaged monthly. Volume, net notional, and gross notional reported in millions.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

Table 2 presents information on transaction prices, averaged annually. We note that CDS spreads, measured in basis points, have dropped over time, while the bid-ask spreads, measured as a percentage, are relatively stable. The increase in the percentage of client-dealer trades reflects the decline in interdealer volume. Additionally, note that the implied bid-ask spread for transactions between dealers and clients that are dealer-initiated is lower, on average, compared to the implied bid-ask spread for transactions that are client-initiated for every year in the data other than 2011.

1.3 Changes in Intermediation Behavior

Beyond the clear decline in CDS market trading throughout our study seen in Tables 1 and 2, we find that intermediation behavior of dealers changed drastically as well.[8] We demonstrate these

[8]During the period that we study, several regulatory reforms were implemented, including the Basel 2.5 and Basel III accords, rules requiring standardized financial contracts be cleared through central counterparties, the Volcker rule, the rules on margin requirements for bilateral transactions, and others. Several papers in the literature study the secondary market for corporate bonds find that, over the same period, liquidity and the behavior of participants has changed – see Adrian et al. (2017); Dick-Nielsen and Rossi (2019); Bessembinder et al. (2018); and Bao et al.

Table 2: Transaction Price Statistics

Year:	2010	2011	2012	2013	2014	2015	2016
CDS Spread (bps)							
Client Trade - Client Initiated	49.62	34.34	32.22	54.79	15.03	14.33	26.45
	(112.09)	(63.20)	(90.87)	(185.12)	(76.43)	(37.03)	(101.38)
Client Trade - Dealer Initiated	49.31	35.55	33.61	55.64	15.90	14.67	27.93
	(112.47)	(67.25)	(92.80)	(203.26)	(84.75)	(43.78)	(105.71)
Interdealer Trade	64.93	35.21	42.66	74.26	12.68	15.23	26.97
	(138.36)	(67.44)	(111.07)	(219.81)	(61.87)	(40.35)	(84.04)
Implied Bid-Ask Spread (%)							
Client Trade - Client Initiated	4.30	3.99	3.96	4.81	4.26	4.52	5.90
	(3.72)	(3.49)	(3.45)	(4.27)	(3.39)	(3.71)	(4.22)
Client Trade - Dealer Initiated	4.58	4.36	3.68	4.25	3.62	3.57	4.92
	(4.10)	(4.09)	(3.54)	(4.22)	(3.34)	(3.21)	(4.30)
Interdealer Trade	5.13	4.83	4.50	5.65	4.49	5.57	5.63
	(4.27)	(4.14)	(3.78)	(4.44)	(3.59)	(4.16)	(3.60)
Proportion of Transactions (%)							
Client Trade - Client Initiated	13.94	14.13	19.54	20.47	21.43	21.78	24.85
Client Trade - Dealer Initiated	11.68	9.50	11.98	12.83	12.36	12.85	16.02
Interdealer Trade	74.37	76.37	68.48	66.70	66.21	65.38	59.13

Note: The CDS spread is the daily average Markit CDS spread, measured in basis points. The bid-ask spread is calculated by finding the distance that a transaction occurs at, relative to the daily Markit CDS spread and is presented as a percentage of the daily Markit CDS spread. The table presents information for both interdealer and client-dealer transactions. Client-dealer transactions are separated into client-initiated, and dealer-initiated, based on which side paid the the implied bid-ask spread. We present the proportion of priced transactions observed by type.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation and Markit Group Ltd.

changes in three ways in this section, and in the the next section, we construct a series of measures that capture these changes to link them to the market provision of liquidity by intermediaries, both individually and collectively.

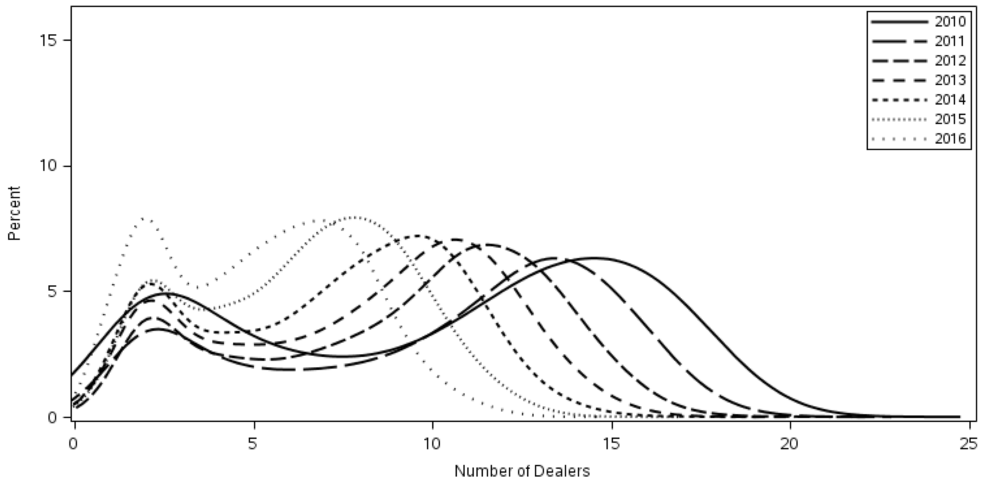
First, we find that overall dealer participation declined. Figure 1 presents the distribution of the number of dealers with non-zero trading volume in each single-name CDS market for each year in our data. The figure illustrates that the number of dealers across all reference entities declines over time.[9]

Second, we find changes in the level of inventory dealers are willing to maintain. Figure 2 shows the distribution of dealer inventories for each year in our data – the inventories are calculated monthly for every single-name reference entity in the data. For each reference entity and each

(2018). Similarly, we find that liquidity in the U.S. single-name CDS market decreased, and identify changes in the behavior of dealers that coincide with the implementation of several of these regulatory reforms.

[9]We find that, on average, it is the smaller dealers that are dropping out from trading each reference entity. We note that this behavior may be due to a declining demand for single-name CDS – this feature is endogenous, and consistent with an increase, to the cost of intermediation.

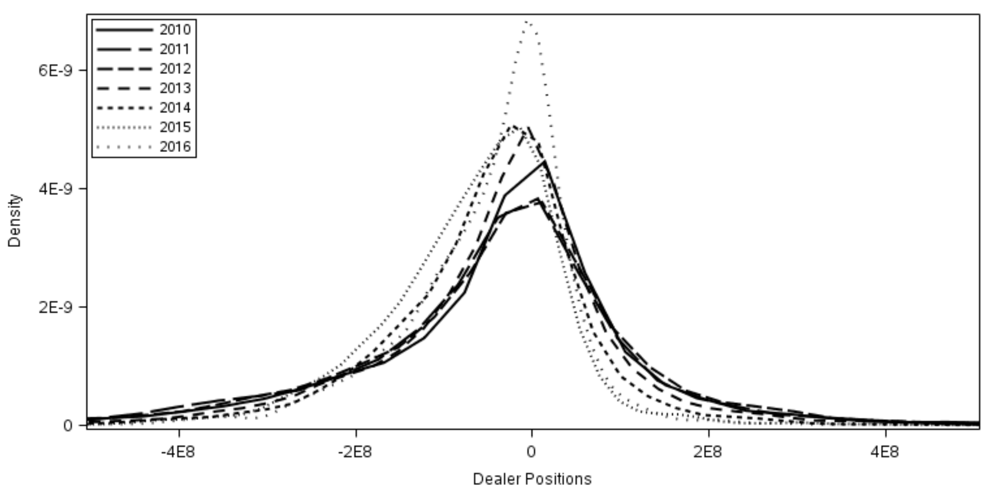
Figure 1: Dealers in the Single-name CDS Market



Note: The plot presents the probability density function of the number of dealers, by year, across our sample of U.S. single-name CDS reference entity markets. The overlay highlights the shrinking number of dealers participating in these markets overtime.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

month, the inventory of a dealer is measured as the notional position of that dealer after netting across all of the dealer's positions with all clients and all other dealers in that reference entity for that month. Consistent with an increased cost of holding inventories, Figure 2 suggests that dealer inventories have tightened over time.

Figure 2: Dealer Net Notional Inventory

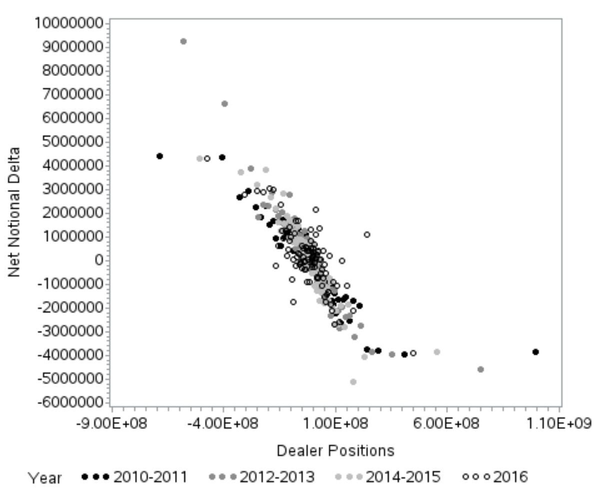


Note: The plot presents the probability density function of weekly dealer positions, by year, across our sample of U.S. single-name CDS reference entity markets. The overlay highlights the tightening of inventory by dealers over time.
Source: Authors' calculations, which use data provided to the OFR by The Depository Trust & Clearing Corporation.

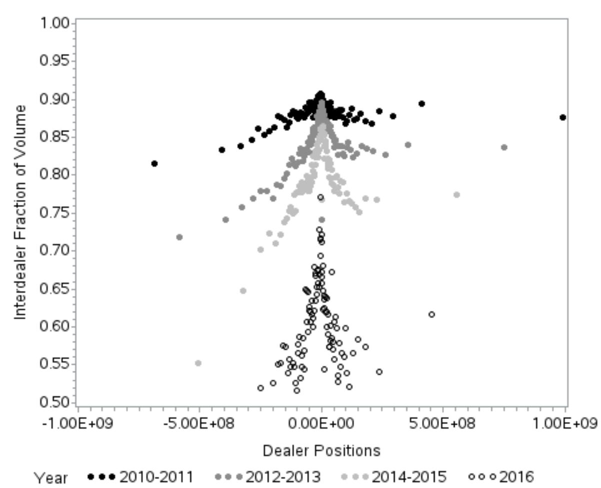
Finally, Figure 3 illustrates changes in inventory management practices in the single-name CDS dealers. The left panel shows dealer week-over-week change in positions grouped by periods.[10] In line with results in the microstructure literature for other markets – see Hansch et al. (1998) – the figure shows that dealers tend to decrease their inventories when they deviate from a net zero position for every year in the data.

The right panel of Figure 3 sheds light on how this reduction is achieved. While interdealer transactions are the most common form of inventory management over all periods, over time dealers are relatively more likely to try to reduce their inventories by trading with clients. This behavior becomes more pronounced the further away the inventories are from zero, and is consistent with the view that trading between dealers has become more difficult, particularly as a function of the level of a dealer's inventory.

Figure 3: Dealer Inventory Management



(a) Weekly Inventory Change given Previous Weeks Inventory



(b) Interdealer Fraction of Trade given Previous Weeks Inventory

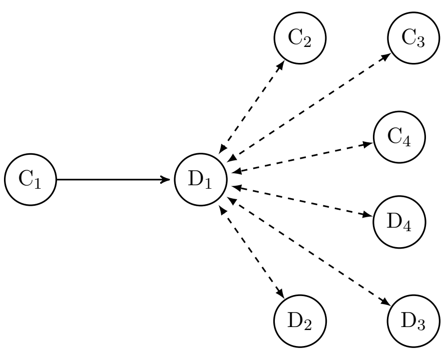
Note: Plots (a) and (b) illustrate changes in inventory management practices in the single-name CDS dealers. Plot (a) shows week-over-week changes in dealer inventory vs. the previous week's inventory. Each point presents the average weekly inventory change grouped by years and centile of previous week dealer inventory. The plot highlights that as inventories grow away from zero, dealers work to reduce their inventory risk. Plot (b) shows the fraction of inventory change corresponding to trades between dealers vs. the previous week's inventory. Each point presents the average weekly fraction of interdealer trade, done by dealers, grouped by years and centile of previous week dealer inventory. The plot illustrates a tightening of inventory by dealers over time, and a growing tendency of dealers to offset inventories with clients when inventories are further from zero.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

[10] Each dot corresponds to a centile of the distribution of net positions in each reference entity for each week.

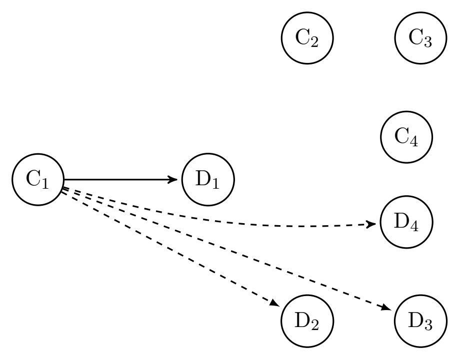
2 Intermediation Network Measures

CDS markets are described in the literature as core-periphery trading networks with dealers in the core of the network and clients on the periphery (Peltonen et al. (2014)). Dealers intermediate client transactions with the expectation that they will be able to reduce the underlying risk of the position they assume by offsetting the risk through interdealer trade or contraposition clients.[11] We present an example of an intermediation network in Figure 4. In the figure, dealer D_1 is intermediating a CDS trade with client C_1 on reference entity j, which is client-initiated. To determine the cost of the transaction, the dealer must consider the liquidity of the market for CDS contracts on reference entity j. She can evaluate the impact of the transaction on her inventory level, x_{1j}, and/or assess her ability to offset the risk of the position by trading with other counterparties. The ease of offloading the risk and whether the transaction brings the level of the inventory of the dealer closer or further from her preferred inventory level, is likely to influence the execution cost, $\mu_{1,j}$, and the bid-ask spread offered, $\gamma_{i,j}$, by the dealer.

Figure 4: Intermediation Network



(a) Dealer Intermediation Network



(b) Client Intermediation Network

Note: Figures (a) and (b) present an example network of trade relationships for dealer D_1 and client C_1. The nodes represent dealers, D_i, and clients, C_j, in a single-name CDS market and the links represent trade relationships. The solid line link represents a trade done between D_1 and C_1. The dashed lines in (a) and (b) represent possible alternative trades for D_1 and C_1.
Source: Authors' creation.

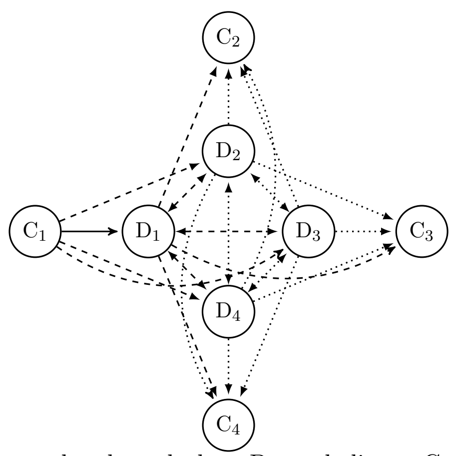
The ease of offsetting the risk associated with holding inventory depends on a dealer's relationships with other market participants, with whom it has prearranged trading agreements (Siriwardane (2019)). These relationships are illustrated by the dashed lines in Figure 4a. The more

[11] We note that, unlike traditional debt securities which can be difficult to borrow, it is relatively easy to short a CDS contract.

market participants a dealer or client has agreements with, the higher the likelihood it will transact at a lower execution cost. In setting prices, and in an effort to attract the transaction, the dealer must consider the client's potential other options, as shown in Figure 4b.

We note that, in equilibrium, the costs associated with transacting and the liquidity of the CDS market, involve considerations beyond the immediate options available to the dealer, D_1, or the client, C_1. Figure 5 provides a simple example of an intermediation network. The figure illustrates that the counterparties of D_1 and C_1 have their own trading options, which will influence the market's overall liquidity. The overall market intermediation network can influence the ability of market participants to transact, the cost to transact, and the overall participation in the market.

Figure 5: Market Intermediation Network



Note: The figure presents a trading network, where dealers, D_i, and clients, C_j, are nodes and links represent trade relationships. The solid line link represents trade between D_1 and C_1. The dashed lines represented the possible direct options of other dealers and clients that D_1 and C_1 could have traded with. The dotted lines represent the possible set of other relationships in the market which indirectly influence the trading decisions and costs of D_1 and C_1.
Source: Authors' creation.

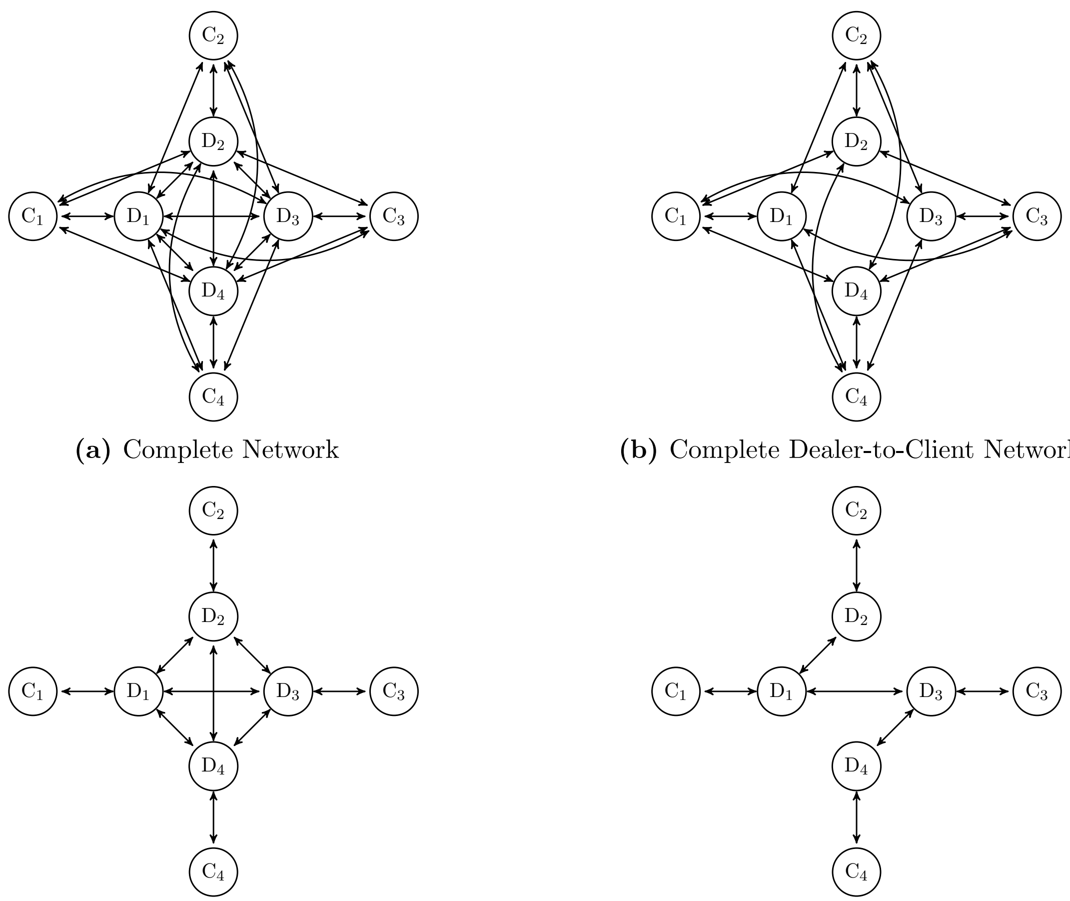
2.1 Network Measures

To measure the degree of intermediation in an OTC market, we introduce measures that quantify relationships between dealers and relationships between dealers and clients. We illustrate these measures through examples of intermediation networks, presented in Figure 6. In all cases, we assume that clients can only connect to one or more dealers but not to each other.[12]

[12]The literature considers additional measures, such as eigenvector centrality, to measure the strength of the relationships in a network. Given the detailed information available in our data, and the difficulty to simultanesouly apply the measures in the literature to multiple networks – e.g., the interdealer and dealer-to-client networks – we

Figure 6a presents a complete network; i.e., a network where every client is connected to every dealer and where every dealer is connected to every other dealer. Figures 6b and 6c present examples where either the dealer-to-client network or the interdealer network is complete, but the other network is sparse. Figure 6d presents a sparse network, where no client or dealer is connected to all dealers.

Figure 6: OTC Network Completeness



(a) Complete Network **(b)** Complete Dealer-to-Client Network

(c) Complete Interdealer Network **(d)** Sparse Network

Note: Figures (a)-(d) present examples of trading networks that vary in their completeness (density) of relationships. Dealers, D_i, and clients, C_j, are depicted as nodes, and links represent established trade relationships between firms. Network (a) represents a complete network where all dealers have relationships with all other dealers and all clients. Networks (b) and (c) represent examples where the dealer-to-client network, or interdealer network, is complete, but the dealer-client network is sparse. Finally, network (d) shows a sparse network where no client or dealer is connected to all dealers.
Source: Authors' creation.

We measure the degree of counterparty relationships for a market participant i by translating the trading network into an adjacency matrix A, where a_{ij} is equal to 1 if parties i and j are

have not considered using these measures.

connected and zero otherwise. The number of relationships for participant i are given by

$$k_i = \sum_{i \neq j} a_{ij}, \quad i, j \in \mathcal{M} \tag{1}$$

where the sum is over all market participants in a particular CDS market, $\mathcal{M}$.

2.1.1 Individual Dealer Network Completeness

We measure the completeness of a dealer's network of relationships relative to a complete set of counterparties in two subsets: dealers, $\mathcal{D}$, and clients, $\mathcal{C}$, defined as

$$\textbf{Interdealer Dealer Completeness}: \mathrm{k}_i^{\mathrm{D}} = \frac{\sum_{j \neq i} a_{ij}}{|\mathcal{D}| - 1}, \quad i, j \in \mathcal{D}; \tag{2}$$

$$\textbf{Client Dealer Completeness}: \mathrm{k}_i^{\mathrm{C}} = \frac{\sum_{j \neq i} a_{ij}}{|\mathcal{C}|}, \quad i \in \mathcal{D}, j \in \mathcal{C}. \tag{3}$$

2.1.2 Market Network Completeness

We measure the completeness of the network for the entire market by counting the number of counterparty relationships relative to that of the complete set of market participant pairs in two subsets: dealers, $\mathcal{D}$, and clients, $\mathcal{C}$. The number of counterparty relationships in a complete market in each case are $|\mathcal{D}|(|\mathcal{D}| - 1)/2$ and $|\mathcal{D}||\mathcal{C}|$, respectively.

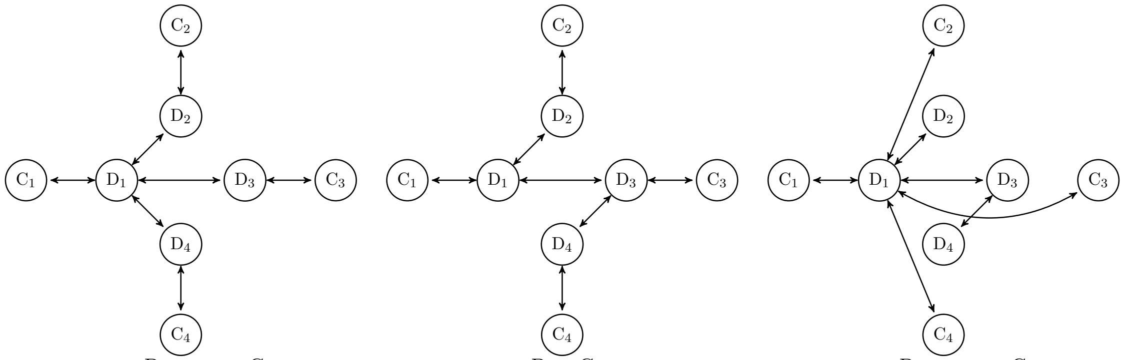
$$\textbf{Interdealer Market Completeness}: \ \mathrm{K}^{\mathrm{D}} = \frac{\sum_i \sum_{j > i} a_{ij}}{|\mathcal{D}|(|\mathcal{D}| - 1)/2}, \quad i, j \in \mathcal{D}; \tag{4}$$

$$\textbf{Client Market Completeness}: \ \mathrm{K}^{\mathrm{C}} = \frac{\sum_i \sum_j a_{ij}}{|\mathcal{D}||\mathcal{C}|}, \quad i \in \mathcal{D}, j \in \mathcal{C}. \tag{5}$$

2.2 Intermediation Network Competition and Concentration

Figure 7 illustrates how the dealer measures capture characteristics of the network for individual firms. The number of relationships between dealers and the number of connections between clients and dealers is the same in Figure 7, but the networks are different. Consider Figure 7b as the base case, with a trade network where no dealer is connected to all other dealers or all clients, such the client dealer completeness and the interdealer dealer completeness are equal to 25 percent and 67 percent for dealer D_1. In this network, dealer D_1 and D_3 have a privileged position with respect to other dealers but no complete relationships.

Figure 7: OTC Network and Dealer Liquidity



(a) High k_1^D, Low k_1^C for D_1 Network **(b)** Low k_1^D, k_1^C for D_1 Network **(c)** Low k_1^D, High k_1^C for D_1 Network

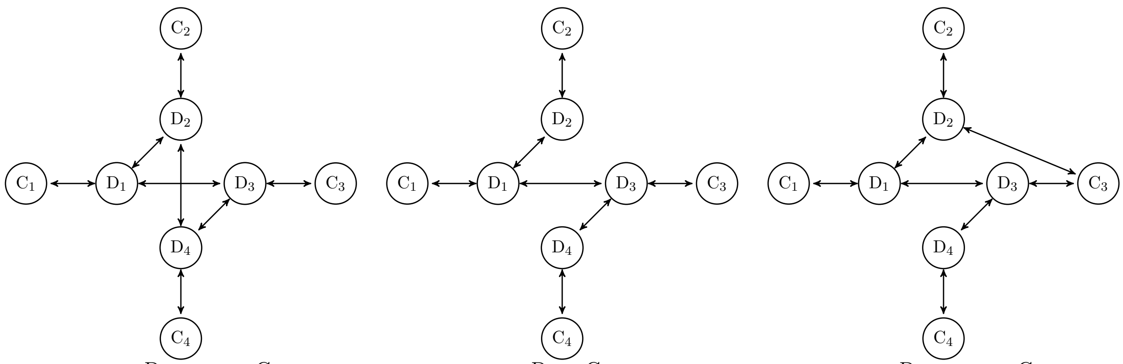
Note: Figures (a)-(c) present example trading networks where dealers, D_i, and clients, C_j, are depicted as nodes and links represent established trade relationships between firms. The variations across the networks highlight differences in k_1^D, k_1^C for dealer D_1 while keeping K^D and K^C the same. Network (b) is the base case and represents a sparse trading network where D_1 has one out of four client relationships in the dealer-to-client market and two out of three dealer relationships in the interdealer market. Network (a) represents a complete interdealer trading network for D_1, such that all dealer intermediation flows through D_1. Network (c) represents a complete dealer-to-client trading network for D_1, where all client intermediation flows through D_1.
Source: Authors' creation.

Figure 7a is a trade network where the client relationships remain the same as Figure 7b but the interdealer relationships are different. Dealer D_1 is connected to every other dealer while other dealers are only connected to dealer D_1. In this case, the client-dealer completeness and the interdealer completeness are equal to 25 percent and 100 percent respectively, for dealer D_1. This is an example of a network where dealer D_1 has more options to rebalance its inventory relative to other dealers and potentially more bargaining power.

Figure 7c is a trade network where the dealer relationships are the same as in Figure 7b, but the client relationships are different. Now, only dealer D_1 is connected to clients, while other dealers are not. For dealer D_1, the completeness of the client-dealer network is equal to 100 percent, while the completeness of her interdealer network is equal to 67 percent. Similar to the previous case, in this trade network, the bargaining power of dealer D_1 is potentially larger relative to the other dealers. However, the bargaining power is based on the dealer's relationships with clients rather than other dealers, allowing her to directly intermediate CDS inventory with clients.

Figure 8 illustrates how the market measures capture the characteristics of the entire markets interconnectedness. Unlike the previous examples, the number of relationships between dealers and the number of relationships between clients and dealers is not constant. However, in this figure, the network completeness measures for dealer D_1's are held constant. Consider Figure 8b the base case again, with a trade network where no dealer is connected to all other dealers or to all clients. In this case, the client market completeness and the interdealer market completeness are equal to 25 percent and 50 percent respectively. In this network dealers D_1 and D_3 have a privileged position with respect to other dealers since they each have relationships with two other dealers, but no dealer has a complete interdealer or client network.

Figure 8: OTC Network and Market Liquidity



(a) High K^D, Low K^C for D_1 Network

(b) Low K^D, K^C for D_1 Network

(c) Low K^D, High K^C for D_1 Network

Note: Figures (a)-(c) present example trading networks where dealers, D_i, and clients, C_j, are depicted as nodes and links represent established trade relationships between firms. The variations across the networks highlight differences in K^D and K^C while keeping k_1^D and k_1^C the same for dealer D_1. Network (b) is the base case and represents a sparse market network. Network (a) represents an increase in the completeness of the interdealer market network relative to (b). Network (c) represents an increase in the completeness of the dealer-to-client market network relative to (b). *Source*: Authors' creation.

Figure 8a is a trade network where the D_1's interdealer relationships remain the same as Figure 8b but a new interdealer relationship exists between D_2 and D_4. The result is no dealer has a privileged position with respect to other dealers, and the client market completeness and the interdealer market completeness are equal to 25 percent and 66 percent. The example of the market network change with respect to dealer D_1 has no clear direct effect on its liquidity. Additionally, it's not clear what this change will do to the new equilibrium rebalancing of D_1's inventory relative to Figure 8b, and, and whether it should expect to see a decrease or increase in trading costs due to this indirect change to its network.

Figure 8c is a trade network where the D_1's client relationships remain the same as Figure 8b but a new client relationship exists between client C_3 and dealer D_2. In this case, the completeness of the client market network and the interdealer market network are equal to 33 percent and 50 percent respectively. The change in the market network has no clear direct effect on dealer D_1, when compared to Figure 8b, but may have an indirect effect.

We note that both figures suggest that additional relationships in the market networks or the networks of individual dealers, may have an impact on intermediation, and potentially result in a measurable difference in the liquidity of trades, either between dealers and clients, between dealers, or both. In Section 3 we present a series of hypotheses that explore these consequences and use our data to test them empirically in Section 4.

2.3 Intermediation Network Statistics

Table 3 presents annual statistics for network measures. We note that the number of dealers per single-name reference entity declines over time, while the number of clients remains relatively stable. The network measures reveal that the completeness of the interdealer networks declines, both at the individual dealer-level and the market-level. On the other hand, we don't observe the same decline in the dealer-to-client networks – especially at the market-level where market completeness between dealers and clients increases.[13]

[13]To be able to compute the network measures, and to ensure significant variation in trading volume, we limit the data throughout our study to reference entities with at least 4 dealers with non-zero positions during the entire sample period.

Table 3: CDS Intermediation Network Statistics per Single-name Reference Entity

Year:	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
# of Dealers	10.1	10.1	9.1	8.1	7.2	6.4	5.2
	(0.9)	(4.8)	(4.1)	(3.8)	(3.4)	(2.9)	(2.7)
# of Clients	4.3	5.2	5.3	4.5	4.3	4.1	4.4
	(0.6)	(6.5)	(6.8)	(6.3)	(5.9)	(5.2)	(4.9)
Interdealer Dealer Completeness (%)	68.7	69.9	70.0	66.8	65.8	59.6	55.5
	(12.3)	(9.8)	(7.8)	(8.4)	(8.5)	(8.7)	(8.4)
Client Dealer Completeness (%)	22.4	20.9	19.6	18.8	18.7	20.2	18.7
	(15.3)	(14.7)	(13.5)	(9.7)	(6.4)	(9.4)	(8.3)
Interdealer Market Completeness (%)	60.1	62.0	63.9	62.4	61.7	56.5	53.0
	(13.6	(10.3)	(8.5)	(8.2)	(8.5)	(9.3)	(9.3)
Client Market Completeness (%)	10.7	10.3	10.6	11.0	10.9	11.8	11.3
	(3.9)	(2.4)	(2.3)	(2.7)	(2.1)	(4.3)	(3.7)

Note: The table presents annual summary statistics for the number of dealers, number of clients, and completeness measures for intermediation networks at the individual dealer-level, as well as at the aggregate market-level.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

3 Intermediation Network & Market Liquidity Hypotheses

How and why OTC market trade networks form is a function of several potential frictions such as search costs, transaction costs either between dealers or dealers and clients, and dealer inventory. Additionally, changes in CDS reference entity supply and demand may influence the trade network. For example, an increase in client demand may lead to additional trade relationships between clients and dealers, or new clients participating in a CDS market. However, regardless of the cause of friction, the completeness of an intermediation network provides an observable measure of a market's ability to support efficient trade. In this section, we outline seven hypotheses on the relationships between OTC network completeness and measures of a dealer and the market's liquidity.

H1: *The completeness of a market's intermediation network is positively related with the market's trade volume.*

The intuition behind H1 is that network completeness, either in terms of the interdealer network or the dealer-to-client network, allows for more efficient trading as it increases the opportunities of finding a counterparty with whom one can trade. The hypothesis postulates that this ease translates to higher trade volume. H1 is consistent with Babus and Kondor (2018) findings which suggest that increased completeness of a dealer should lead to an increase in the dealer's propensity to learn more through trade such that it may lower its costs, and earn a higher expected profit. Generalizing this finding further, we should expect that a better-informed market, measured through the completeness of the market's trading network, is associated with higher trading volumes. However, increased completeness may also decrease trade volume as fewer intermediation trades are necessary (Gofman (2017)).

H2: *An increase in the intermediation trade volume among dealers is negatively related to the share of the market's trade volume in the dealer-to-client network.*

H2 is based on a theoretical model of network trading by Wang (2018). The model accounts for both dealer inventory costs and transaction costs in the interdealer and dealer-to-client networks. The intuition is that an increase in the intermediation volume among dealers is related to lower transaction costs of dealers or higher dealer inventory costs. In either case, dealers offset a larger share of their risk by trading with other dealers, and their share of trading increases relative to the share of trading between dealers and clients.

H3: *The completeness of a market's intermediation network is negatively related to the number of dealers in a market.*

The intuition behind H3 is that an increase in the completeness of the intermediation network allows dealers to better search and reduce individual inventories. The setting is in line with the theoretical proposition in Carapella and Monnet (2020), where the number of dealers is reduced as their search options increase; ie, the market increases in concentration. We note that a competing hypothesis is also plausible, as increased completeness is associated with higher trading volume, potentially allowing additional dealers to enter the market, leading to a decrease in market concentration.

H4: *The completeness of a dealer's intermediation network is positively related to the dealer's risk bearing capacity, i.e. the dealer's net inventory.*

This hypothesis focuses on individual dealer's inventory management. Similar to much of the theoretical literature, H4 suggests that a dealer with more complete networks is able to bear more risk. Neklyudov (2019) finds that dealers with better search technology, i.e. more well-connected dealers, finds trade opportunities more easily, and thus have relatively higher trade execution efficiency. The increased efficiency lowers the risk of well-connected dealers' inventories and allows them to take on higher inventory levels (Gofman (2017)).

H5: *The completeness of a market's intermediation network, controlling for the completeness of the intermediation network of individual dealers, is:*

a. positively related to the risk-bearing capacity of individual dealers, their net inventory;

b. positively related to the gross risk-bearing capacity of all dealers, the total net inventories of dealers.

In contrast to the previous hypothesis, H5 focuses on the completeness of the market network, rather than the network of an individual dealer. The intuition behind the hypothesis is that network completeness allows dealers to cheaply find counterparties to offload their inventory, leading to smaller dealer inventories. At the same time, the gross size of dealer positions increases because the risk-bearing capacity of the aggregate network becomes larger. The work of Yang and Zeng (2019) suggests that dealers only provide more liquidity if other dealers do so due to strategic coordination motives. When the inventory management costs are sufficiently low (high), a dealer is more (less) willing to provide liquidity in the sense of buying an asset from a counterparty, holding a high level of inventory, and then selling the asset to a buyer later. This implies a higher (lower) aggregate dealer inventory and a larger (smaller) dispersion of inventory distribution among dealers. The intuition behind Neklyudov (2019) suggests a similar outcome though it is driven on inventory risk generally, rather than simply interdealer coordination concerns. Gofman (2011) finds that the bilateral bargaining frictions of OTC markets, efficient allocation can occur only when the trading network is complete.

H6: *The completeness of a dealer's intermediation network is negatively related to the execution cost and the bid-ask spread faced by individual dealers.*

This hypothesis focuses on the completeness of the network of an individual dealer and is similar to propositions on dealer centrality found in the literature. The intuition is that a dealer with a more complete network is able to trade at lower execution costs and consequently, can offer better bid-ask spreads to its counterparties. Babus and Kondor (2018) model predicts that this feature is due to less client concern regrading adverse selection from dealers and well-connected dealers having increased ability to learn prices from several other transactions. These expectations of centrality are consistent with the empirical findings in Hollifield et al. (2017) and Di Maggio et al. (2017) of the corporate bond market. However, both of these works are limited in that they only observe interdealer networks when assessing trade costs. As a result, it remains unclear as to how important each part of a dealer's network is in influencing the cost of a trade.

H7: *The completeness of a market's intermediation network, conditional on the completeness of the intermediation network of individual dealers, is negatively related to the execution cost and bid-ask spreads faced by individual dealers.*

In contrast to the previous hypothesis, H7 focuses on the completeness of the intermediation network of the entire market, rather than a specific dealer. However, the intuition is similar. In markets that are complete, it is cheaper to execute transactions and bid-ask spreads are lower. Babus and Kondor (2018) find that under a theoretical OTC market setting that a determinant of a dealer's trading cost, besides her own centrality, is the centrality of her counterparties.

Empirically, Hollifield et al. (2017) and Di Maggio et al. (2017) find that the centrality of both dealer counterparties matter for assessing the cost of a trade. However, since both of these works are limited to observation of the interdealer network when assessing trade cost, it is not clear whether these findings will hold once one controls for each dealer's interdealer and dealer-to-client networks. As a result, one must consider the relative bargaining power of dealers with respect to the entire market in order to assess the equilibrium cost of a trade.

4 Empirical Study of Intermediation Networks

In this section, we empirically assess whether network characteristics can be used to explain market liquidity by testing the hypotheses outlined in Section 3. We examine the relationship of the intermediation network metrics discussed in Section 2 against several liquidity metrics, such as market volume, execution cost of a trade, and bid-ask spreads, using models which control for dealer, market, substitute market, and time effects.[14]

[14] Table A.1 in the Appendix provides a full list the variables we use in our models.

4.1 Dealer-Client Volume

Our first measure of market liquidity is market volume, specifically client trade volume (λ^{C}). To test hypothesis H1, we construct a model for the determinants of client volume (λ_j^{C}) for the market of single-name CDS contracts for reference entity j. The model includes both fundamental drivers of the demand for CDS contracts, such as the riskiness of the underlying name and hedging needs, as well as the measures of completeness of the interdealer (K^{D}) and the dealer-to-client (K^{C}) market networks. The model is given by

$$\begin{aligned} \log(\lambda_{j,t}^{\mathrm{C}}) =& \beta_0 + \beta_1 \text{CDS Spread}_{j,t} + \beta_2 \Delta\text{CDS Spread}_{j,t} \\ &+ \beta_3 \text{CDS Recovery Rate}_{j,t} + \beta_4 \log(\text{Index } \lambda_t^{\mathrm{C}}) \\ &+ \beta_5 \log(\text{Bond } \lambda_{j,t}) + \beta_6 \mathbb{1}_{j,t}^{\text{Clearable}} + \beta_{7-17} \mathbb{1}^{\mathrm{M}} + \beta_{18-79} \mathbb{1}^{\mathrm{M/Y}} \\ &+ \beta_{80} \mathrm{K}_{j,t}^{\mathrm{D}} + \beta_{81} \mathrm{K}_{j,t}^{\mathrm{C}} + \beta_{82} \lambda_{j,t}^{\mathrm{D}} / \lambda_{j,t} + \epsilon. \end{aligned} \tag{6}$$

The time period, t, in the regression model in Equation (6) is one week – all variables are calculated each week. Since many single-name CDS contracts transact relatively infrequently, we calculate the weekly network measures for the completeness of the interdealer and client networks over the previous month using a rolling window. The results, reported in Table 4, indicate a significant relationship between the risk of a reference entity and the trading volume for the corresponding CDS contract. The CDS spread and its estimated recovery rate is significantly positively correlated with volume.[15] As a risk, measured by CDS spreads, increases, we expect hedging demand by holders of existing debt to also increase. The results are consistent with CDS volumes being positively correlated with CDS spreads.

With the introduction of central counterparties clearing to U.S. CDS markets within our sample period, we incorporate a clearing indicator for each single-name reference entity corresponding to when that reference entity became eligible to clear at a U.S. central counterparty. We find the eligibility of a CDS contract to be cleared is positively correlated with increasing volume. This result is consistent with the fact that clearing eligibility is largely based on whether a particular

[15] The recovery rate represents the extent to which principal and accrued interest on defaulted debt can be recovered. Higher credit quality debt has higher recovery rates and is typically correlated with the size of traded debt outstanding.

Table 4: Intermediation Network and Client Volume

	Dependent Variable				
	log(Client Volume)				
	(1)	(2)	(3)	(4)	(5)
Intercept	4.307***	4.160***	3.813***	3.980***	3.459***
Interdealer Volume Share		-0.009***			-0.010***
Interdealer Market Completeness			0.008***		0.007***
Client Market Completeness				0.037***	0.026***
CDS spread	1.436***	1.478***	1.374***	1.188***	1.246***
ΔCDS spread	-0.072	-0.145	-0.045	0.011	-0.062
CDS Recovery Rate	0.805***	0.753***	0.667***	0.696***	0.545***
log(Bond Volume)	0.115***	0.117***	0.121***	0.109***	0.119***
log(Client Index CDS Volume)	0.157***	0.234***	0.157***	0.160***	0.236***
CDS Clearing Eligible	0.068***	0.034***	0.082***	0.105***	0.072***
Time Fixed Effects	Y	Y	Y	Y	Y
Observations	38,519	38,519	38,519	38,519	38,519
Adjusted R^2	9.3%	26.4%	10.3%	10.3%	28.4%

Note: The table presents the results of Equation (6) for the relationship between measures of network completeness, characteristics of the underlying reference entity, and client volume.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

CDS contract is part of a CDS index, and index inclusion is based on whether a CDS contract is heavily traded.

Beyond the relationship between fundamental factors that capture the risk of a reference entity and volume for the corresponding CDS contract, Table 4 reveals a significant relationship between intermediation network measures and the volume of trade between dealers and clients. First, the share of interdealer volume, a signal of the degree of difficulty in offsetting trades, increases the explanatory power of the regression substantially. Second, the sign of the coefficient of the share of interdealer volume is negative, meaning that a higher share of interdealer trade is associated with lower client volumes.

In addition, the results indicate that the market network completeness measures are positively related to increased client volume for both the interdealer and the dealer-to-client market networks. This relationship is not only statistically significant but also economically significant. The regression coefficient indicates that an increase in the completeness of the interdealer market network by 10 percent is associated with an increase of dealer-to-client volume by 7-8 percent. Increasing the completeness of the dealer-to-client network at the market-level has a bigger effect. A 10 percent increase in completeness is associated with an increase in dealer-to-client volume by 26-37 percent. These results are consistent with hypothesis H1 and suggest that network completeness is a proxy for lower costs of trading in the network.

4.2 Interdealer Volume Share

The share of interdealer volume in a market captures the amount of intermediation performed in order to offset risk. Hypothesis H2 is based on Wang (2018) which identifies a negative relation between the share of interdealer volume, $\lambda^{\mathrm{D}}/\lambda$, and the volume of transactions between dealers and clients, λ^{C}, in equilibrium. We test whether this prediction holds empirically in our data using the following model:

$$\frac{\lambda^{\mathrm{D}}_{j,t}}{\lambda_{j,t}} = \beta_0 + \beta_1(\log(\lambda^{\mathrm{C}}_{j,t}) \wedge \log(\lambda_{j,t})) + \beta_2 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_{3-84}\mathbb{1}^{\mathrm{M/Y}} + \beta_{85-381}\mathbb{1}^{\mathrm{R}}_{j} + \epsilon. \tag{7}$$

The results, presented in Table 5, are in line with Hypothesis H2; i.e., they confirm a negative and significant relationship between client volume and the share of interdealer volume. Additionally, the results suggest that the introduction of clearing decreases the share of interdealer trade. This finding is likely due to the increased risk-sharing capacity and netting that clearing affords. When central clearing is an option, the capacity of an individual dealer to accommodate trades increases due to the benefits of netting and leads to a decreasing need to offset trades with other counterparties.

Table 5: Inderdealer Share of CDS Volume

	Dependent Variable
	Inderdealer Volume Share
Intercept	248.7***
CDS Clearing Eligible	-5.4***
log(Client Volume)	-23.7***
Time Fixed Effects	Y
Reference Entity Fixed Effects	Y
Observations	38,817
Adjusted R^2	42.4%

Note: The table presents the results of Equation (7) for the relationship between weekly client volume and the interdealer share of volume for single-name CDS contracts.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

4.3 Number of Dealers

The number of dealers ($|\mathcal{D}|$) accommodating trade in a reference entity potentially depends on the demand for trading, the risk-capacity of individual dealers, as well as the risk capacity of the entire network. Hypothesis H3 suggests that the completeness of a market's intermediation network is negatively related to the number of dealers. We investigate the relationship between the number of dealers and network measures of completeness with the model

$$\begin{aligned} |\mathcal{D}_{j,t}| =& \beta_0 + \beta_1 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_2 \mathrm{K}^{\mathrm{D}}_{j,t} + \beta_3 \mathrm{K}^{\mathrm{C}}_{j,t} + \beta_4 \log(\lambda^{\mathrm{C}}_{j,t}) \\ &+ \beta_5 \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} + \beta_{6-87} \mathbb{1}^{\mathrm{M/Y}} + \beta_{88-384} \mathbb{1}^{\mathrm{R}}_{j} + \epsilon. \end{aligned} \tag{8}$$

The results presented in Table 6 find that the relationship between client volume and the number of dealers is insignificant. At the same time, there is evidence that the relationship between the interdealer volume share and the number of dealers is statistically significant. The economic significance is marginal though, with an increase in the share of interdealer volume of 10 percent associated with an increase in the number of dealers by 0.1. On the other hand, consistent with hypothesis H3, we find increased market network completeness in the interdealer and dealer-to-client networks is significant both statistically and economically. An increase in the interdealer market completeness by 10 percent is associated with a decrease in the number of dealers by 0.9-1.0, while a 10 percent increase in dealer-to-client market completeness is associated with a decrease in the number of dealers by 0.8-2.5. The sign of the relationships suggests that more complete networks allow for higher risk capacity for both individual dealers and the entire reference entity market, leading to fewer dealers needed to accommodate demand.

4.4 Individual & Aggregate Dealer Inventory

The size of dealer inventories, both individually (x) and on aggregate (X), depends on many factors including the cost that dealers face in holding inventory or trading with other market participants. These same factors influence the network structure for the interdealer and the dealer-to-client networks, both at the individual dealer-level and at the aggregate market-level. Hypothesis H4 states that for individual dealers, the completeness of their intermediation networks is positively related to their inventory. As far as market completeness, hypothesis H5 expects that controlling

Table 6: Intermediation Network and Number of Market Dealers

	Dependent Variable				
	Number of Dealers				
	(1)	(2)	(3)	(4)	(5)
Intercept	21.4***	21.3***	27.5***	24.0***	27.7***
Interdealer Volume Share		0.001**			0.001***
Interdealer Market Completeness			-0.098***		-0.093***
Client Market Completeness				-0.253***	-0.078***
CDS Clearing Eligible	0.186***	0.190***	0.112***	0.160***	0.115***
log(Client Volume)	-0.010	0.004	0.001	0.000	0.036
Time Fixed Effects	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y
Observations	38,817	38,817	38,817	38,817	38,817
Adjusted R^2	86.9%	86.9%	93.2%	88.4%	93.3%

Note: The table presents the results of Equation (8) for the relationship between measures of network completeness, characteristics of the underlying reference entity, and the number of dealers intermediating the market for a single-name CDS contract.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

for completeness of intermediation networks of dealers should be positively associated with both a dealer's inventory, as well as the aggregate inventory of all dealers in the market.

We study these relationships with two models, one for the inventory of individual dealers and a second for aggregate dealer inventory, by reference entity j:

$$\begin{aligned}\log(x_{i,j,t}) =& \beta_0 + \beta_1 \log(\lambda^{\mathrm{C}}_{j,t}) + +\beta_2 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_3 \mathrm{K}^{\mathrm{D}}_{j,t} + \beta_4 \mathrm{K}^{\mathrm{C}}_{j,t} + \beta_5 \mathrm{k}^{\mathrm{D}}_{i,j,t} + \beta_6 \mathrm{k}^{\mathrm{C}}_{i,j,t} \\ &+ \beta_7 \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} + \beta_{8-89} \mathbb{1}^{\mathrm{M/Y}} + \beta_{90-386} \mathbb{1}^{\mathrm{R}}_j + \epsilon,\end{aligned} \tag{9}$$

$$\begin{aligned}\log(\mathrm{X}_{j,t}) = \beta_0 + \beta_1 \lambda^{\mathrm{C}}_{j,t} + +\beta_2 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_3 \mathrm{K}^{\mathrm{D}}_{j,t} + \beta_4 \mathrm{K}^{\mathrm{C}}_{j,t} \\ + \beta_7 \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} + \beta_{8-89} \mathbb{1}^{\mathrm{M/Y}} + \beta_{90-386} \mathbb{1}^{\mathrm{R}}_j + \epsilon.\end{aligned} \tag{10}$$

Tables 7 and 8 present the results of Equations (9) and (10). Both sets of results suggest that network completeness is associated with the risk capacity and level of inventories of dealers, both individually and on aggregate. In particular, Table 7 shows that explanatory power increases significantly when network measures are included in the model. We find that in contrast with hypothesis H5, after controlling for measures of completeness of intermediation networks of individual dealers, individual dealer inventory declines as the completeness of the interdealer market increases. A 10 percent increase in the completeness of the interdealer market is associated with a 5 percent decrease in individual dealer inventory. This relationship is consistent with a more connected market being able to better spread and net inventories across dealers. The coefficients of individual dealer completeness measures are significant as well, but in line with hypothesis H4, are positive rather than negative, suggesting that better connected individual dealers hold larger inventories. In this case, a 10 percent increase in the completeness of the interdealer network for an individual dealer is associated with a 12 percent increase of its inventory level, while a 10 percent increase in the completeness of the dealer-to-client network of an individual dealer is associated with an increase in its inventory level by 5 percent. These results suggest that dealers with more connections to other dealers and clients have larger risk-bearing capacity, potentially due to their ability to easily reduce their positions in the future (if necessary) through their trading network.

Additionally, the results in Table 8 demonstrate the importance of a market's intermediation network. Consistent with hypothesis H5, regarding aggregate market inventory, as the completeness of the market-level interdealer and the dealer-to-client networks increases, the aggregate inventory levels increase as well. For example, a 10 percent increase in each measure is associated with an increase in the aggregate inventory by 3-4 percent and 11-16 percent respectively. This finding suggests that well-connected networks have higher risk-bearing capacity, which in turn could support liquidity under periods of stress due to high client demand.

4.5 Execution Cost & Bid-Ask Spread

The network of trading relationships between dealers and clients has the potential to influence and reflect the cost of executing a trade, not just of individuals but that of the entire market. Hypothesis H6 states that the completeness of the intermediation network of an individual dealer is negatively related to that dealer's cost of trade; i.e., the execution cost and bid-ask spreads faced by the dealer. In contrast, hypothesis H7 states that the completeness of the market's intermediation network, after controlling for the intermediation network of a dealer, is negatively related to the trade cost faced by the dealer.

Table 7: Intermediation Network and Dealer Inventory

	Dependent Variable				
	log(Dealer ‖Inventory‖)				
	(1)	(2)	(3)	(4)	(5)
Intercept	7.4813***	7.4710***	6.4220***	7.3105***	6.7252***
Interdealer Volume Share		0			0.0001
Interdealer Dealer Completeness			0.0123***		0.0128***
Client Dealer Completeness			0.0050***		0.0047***
Interdealer Market Completeness				0.0027***	-0.0053***
Client Market Completeness				0.0004	-0.0013
CDS Clearing Eligible	0.0093*	0.0096**	0.0274***	0.0104**	0.0270***
log(Client Volume)	0.0012	0.0023	0.0028	0.0009	0.0047**
Time Fixed Effects	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y
Observations	496,619	496,619	496,619	496,619	496,619
Adjusted R^2	9.35%	9.35%	22.24%	9.40%	22.43%

Note: The table presents the results of Equation (9) for the relationship between measures of network completeness, characteristics of the underlying reference entity, and the inventory of individual dealers.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

Table 8: Intermediation Network and Market Inventory

	Dependent Variable				
	log(Σ Individual Dealer ‖Inventory‖)				
	(1)	(2)	(3)	(4)	(5)
Intercept	8.60***	8.55***	8.35***	8.43***	8.24***
Interdealer Volume Share		0.0002***			0.0002***
Interdealer Market Completeness			0.0040***		0.0032***
Client Market Completeness				0.0166***	0.0106***
CDS Clearing Eligible	0.0890***	0.0903***	0.0920***	0.0908***	0.0936***
log(Client Volume)	0.0096***	0.0151***	0.0092***	0.0089***	0.0136***
Time Fixed Effects	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y
Observations	38,811	38,811	38,811	38,811	38,811
Adjusted R^2	86.1%	86.1%	86.5%	86.4%	86.7%

Note: The table presents the results of Equation (10) for the relationship between measures of network completeness, characteristics of the underlying reference entity, and aggregate market inventory for CDS contracts on a single-name reference entity.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

We first consider the execution cost (μ), which we define to be

$$\mu_{i,j,t} = \frac{\text{CDS Transaction Spread}_{i,j,t} - \text{CDS Spread}_{j,t}}{\text{CDS Spread}_{j,t}} (2 \times \mathbb{1}^{\text{buyer}} - 1). \tag{11}$$

The execution cost captures the cost of transacting from the point of view of the entity transacting. For example, if the CDS transaction spread is above the average CDS spread given by Markit, the execution cost is positive for a buyer and negative for a seller.

We construct two models of execution cost from the perspective of a dealer. We present one model for the case when the dealer trades with a client and another for the case when the dealer trades with another dealer.

$$\begin{aligned} \mu^{\text{C}}_{i,j,t} =& \beta_0 + \beta_1 |\mathcal{D}_{j,t}| + \beta_2 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_3 \text{K}^{\text{D}}_{j,t} + \beta_4 \text{K}^{\text{C}}_{j,t} + \beta_5 \text{k}^{\text{D}}_{i,j,t} + \beta_6 \text{k}^{\text{C}}_{i,j,t} + \beta_7 \lambda^{\text{D}}_{j,t}/\lambda_{j,t} \\ &+ \beta_8 \log(x_{i,j,t}) + \beta_9 \log(\text{X}_{j,t}) + \beta_{10} \log(\sum \|x_{i,j,t}\|) + \beta_{11-92} \mathbb{1}^{\text{M/Y}} + \beta_{93-389} \mathbb{1}^{\text{R}}_j + \epsilon \end{aligned} \tag{12}$$

$$\begin{aligned} \mu^{\text{D}}_{i,j,t} =& \beta_0 + \beta_1 |\mathcal{D}_{j,t}| + \beta_2 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_3 \text{K}^{\text{D}}_{j,t} + \beta_4 \text{K}^{\text{C}}_{j,t} + \beta_5 \text{k}^{\text{D}}_{i,j,t} + \beta_6 \text{k}^{\text{C}}_{i,j,t} + \beta_7 \lambda^{\text{D}}_{j,t}/\lambda_{j,t} \\ &+ \beta_8 \log(x_{i,j,t}) + \beta_9 \log(\text{X}_{j,t}) + \beta_{10} \log(\sum \|x_{i,j,t}\|) + \beta_{11-92} \mathbb{1}^{\text{M/Y}} + \beta_{93-389} \mathbb{1}^{\text{R}}_j + \epsilon \end{aligned} \tag{13}$$

Table 9 presents the results for the dealer execution cost for dealer-to-client transactions. We note that the execution cost increases with the size of the dealer's inventory, suggesting that dealers with large inventories have difficulty offloading risk when trading with clients. On the other hand, execution cost decreases with the size of the market inventory, which suggests it is easier to offload risk with clients in larger markets. We do not find support for hypotheses H6 and H7 regarding the link between completeness measures and dealer execution cost when trading with clients, as the execution cost does not exhibit significant dependence on any network measures.

Table 10 presents the results for the interdealer execution cost. Unlike the case of transactions between dealers and clients, the execution cost no longer depends on individual dealer inventories. The execution cost depends on whether contracts on a reference entity are eligible to clear. We find eligible to clear contracts are more expensive to trade among other dealers by 6-15 basis points. We find some support for hypothesis H6, as we find that a 10 percent increase in a dealer's client

Table 9: Intermediation Network and Dealer-to-Client Execution Cost

	Dependent Variable									
	Execution Cost									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intercept	17.93*	17.9149	18.1596*	18.6753*	18.5967*	12.3347	12.3173	12.7305	13.8079	13.7168
Interdealer Volume Share		0.0004			0.0004		0.0004			0.0004
Interdealer Dealer Completeness			-0.0110		-0.0103			-0.0122		-0.0101
Client Dealer Completeness			0.0137		0.0142			0.0140		0.0145
Interdealer Market Completeness				-0.0104	-0.0033				-0.0166	-0.0098
Client Market Completeness				-0.0065	-0.0312				-0.0134	-0.0387
log(Dealer ‖Inventory‖)	0.4213***	0.4214***	0.4091***	0.4198***	0.4067**	0.4088***	0.4088***	0.3976**	0.4065**	0.3922**
log(‖Net All Dealer Inventory‖)	-0.1907	-0.1914	-0.1833	-0.1900	-0.1812	-0.3311	-0.3317	-0.3218	-0.3263	-0.3184
log(All Dealer ‖Inventory‖)	-1.8847*	-1.8855*	-1.7885*	-1.7514	-1.7156					
log(All Long Dealer Inventory)						-0.7233	-0.7224	-0.6960	-0.6698	-0.6648
log(All Short Dealer ‖Inventory‖)						-0.4263	-0.4277	-0.3597	-0.2897	-0.2553
CDS Clearing Eligible	0.3577	0.3617	0.3174	0.3477	0.3146	0.3136	0.3174	0.271	0.2974	0.2633
Number of Market Dealers	-0.0684	-0.0684	-0.0934	-0.1240	-0.1233	-0.0713	-0.0713	-0.0991	-0.1613	-0.1609
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	295,327	295,327	295,327	295,327	295,327	295,327	295,327	295,327	295,327	295,327
Adjusted R^2	1.91%	1.91%	1.91%	1.91%	1.91%	1.90%	1.90%	1.91%	1.90%	1.91%

Note: The table presents the results of Equation (12) for the relationship between measures of network completeness, characteristics of dealer inventories, characteristics of the underlying reference entity, and the execution cost of a transaction for a trade between a client and a dealer.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

network completeness decreases their interdealer execution trade by 41-43 basis points. However, we do not find support for hypothesis H7 after controlling for a dealer's client network. This finding may be potentially due to the link between interdealer trade costs and a dealer's need to offset the trade. As the collective market of dealers grows more directly connected to clients, the need for the interdealer market declines and execution costs grow.

Next, we measure the cost of trading a CDS contract through the magnitude of the bid-ask spread. Since we do not observe bid or ask quotes, we follow the literature and estimate the bid-ask spread by measuring the distance between the credit spread of a specific transaction and the average CDS spread given by Markit.[16] We define the bid-ask spread (γ) to be:

$$\gamma_{i,j,t} = \left| \frac{\text{CDS Transaction Spread}_{i,j,t} - \text{CDS Spread}_{j,t}}{\text{CDS Spread}_{j,t}} \right|. \tag{14}$$

We construct two models of bid-ask spread, with one estimating transactions spreads between dealers and clients, and the other for transactions between dealers.

$$\begin{aligned} \gamma^{\mathrm{C}}_{i,j,t} = &\beta_0 + \beta_1|\mathcal{D}_{j,t}| + \beta_2 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_3 \mathrm{K}^{\mathrm{D}}_{j,t} + \beta_4 \mathrm{K}^{\mathrm{C}}_{j,t} + \beta_5 \mathrm{k}^{\mathrm{D}}_{i,j,t} + \beta_6 \mathrm{k}^{\mathrm{C}}_{i,j,t} + \beta_7 \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} \\ &+ \beta_8 \log(x_{i,j,t}) + \beta_9 \log(\mathrm{X}_{j,t}) + \beta_{10} \log(\sum \|x_{i,j,t}\|) \\ &+ \beta_{11-92} \mathbb{1}^{\mathrm{M/Y}} + \beta_{93-389} \mathbb{1}^{\mathrm{R}}_j + \epsilon, \end{aligned} \tag{15}$$

$$\begin{aligned} \gamma^{\mathrm{D}}_{i,j,t} = &\beta_0 + \beta_1|\mathcal{D}_{j,t}| + \beta_2 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_3 \mathrm{K}^{\mathrm{D}}_{j,t} + \beta_4 \mathrm{K}^{\mathrm{C}}_{j,t} + \beta_5 \mathrm{k}^{\mathrm{D}}_{i,j,t} + \beta_6 \mathrm{k}^{\mathrm{C}}_{i,j,t} + \beta_7 \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} \\ &+ \beta_8 \log(x_{i,j,t}) + \beta_9 \log(\mathrm{X}_{j,t}) + \beta_{10} \log(\sum \|x_{i,j,t}\|) \\ &+ \beta_{11-92} \mathbb{1}^{\mathrm{M/Y}} + \beta_{93-389} \mathbb{1}^{\mathrm{R}}_j + \epsilon. \end{aligned} \tag{16}$$

Table 11 presents the results for the magnitude of the bid-ask spread for transactions between dealers and clients. The table shows that the bid-ask spread is smaller for markets with many dealers, likely due to increased competition. The bid-ask spread also declines with the size of the inventory of individual dealers, suggesting that clients can achieve better prices when dealers hold large inventories. The bid-ask spread does increase with the total, aggregate, market inventory,

[16] Iercosan and Jiron (2017) use the same process for estimating the bid-ask spread.

Table 10: Intermediation Network and Interdealer Execution Cost

	Dependent Variable									
	Execution Cost									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intercept	0.2314	0.2201	0.6452	0.2513	0.5861	0.1081	0.0969	0.4429	0.1407	0.3824
Interdealer Volume Share		0.0001			-0.0001		0.0001			-0.0001
Interdealer Dealer Completeness			0.0090		0.0106			0.0089		0.0106
Client Dealer Completeness			-0.0411***		-0.0425***			-0.0411***		-0.0425***
Interdealer Market Completeness				-0.0011	-0.0093				-0.0012	-0.0094
Client Market Completeness				0.0076	0.0787***				0.0075	0.0788***
log(Dealer ‖Inventory‖)	-0.0095	-0.0094	0.0619	-0.0096	0.0608	-0.0097	-0.0096	0.0618	-0.0097	0.0606
log(‖Net All Dealer Inventory‖)	0.0062	0.0062	0.0037	0.0055	-0.0037	0.0033	0.0032	-0.0048	0.0031	-0.0069
log(All Dealer ‖Inventory‖)	-0.0945	-0.0945	-0.2168*	-0.0920	-0.2282**					
log(All Long Dealer Inventory)						-0.0325	-0.0330	-0.0928*	-0.0287	-0.0637
log(All Short Dealer ‖Inventory‖)						-0.0478	-0.0472	-0.0997	-0.0488	-0.142**
CDS Clearing Eligible	0.0644***	0.0652***	0.1511***	0.0633***	0.1469***	0.0639***	0.0647***	0.1501***	0.0626***	0.1458***
Number of Market Dealers	0.0089	0.0088	0.0285	0.0067	0.0225	0.0089	0.0088	0.0286	0.0062	0.0217
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312
Adjusted R^2	0.02%	0.02%	0.10%	0.02%	0.10%	0.02%	0.02%	0.10%	0.02%	0.10%

Note: The table presents the results of Equation (13) for the relationship between measures of network completeness, characteristics of dealer inventories, characteristics of the underlying reference entity, and the execution cost of a transaction for a trade between dealers.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

although not with the net market inventory. This result suggests that bid-ask spreads between dealers and clients increase with the volume of trading, even when trading is balanced. In line with hypothesis H6, the network measures indicate that the dealer-to-client bid-ask spreads are smaller when the individual dealers are better connected to other dealers. This result is consistent with results in the literature for the corporate bond market that show that dealers that are more central are better able to share risk and can pass along this additional liquidity, in the form of smaller bid-ask spreads, to their clients.

Table 12 presents the results for the magnitude of the bid-ask spread for inderdealer transactions. Similar to transactions between dealers and clients, the table shows that the bid-ask spread is smaller for markets with many dealers. The bid-ask spread increases with the aggregate market inventory. Additionally, it increases when CDS contracts are eligible for clearing by 81-95 basis points, a further indication that clearing may increase costs for dealers. Among the network measures, we do not find support for hypothesis H6 as the completeness of the intermediation network of individual dealers is not significant. However, there is support for hypothesis H7, as the market measures are significant for both the interdealer and the dealer-to-client networks. In both cases we find that the more well-connected a trade network is, the narrower is the bid-ask spread of that reference entity. The result highlight that well-connected networks allow for lower trading costs and is consistent with a larger risk-sharing capacity by intermediaries.

Table 11: Intermediation Network and Dealer-to-Client Bid-Ask Spreads

	Dependent Variable									
	Bid-Ask Spread									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intercept	9.1563	9.3392	13.9083**	14.1631*	16.2607**	7.223	7.436	12.3557*	13.143*	15.1492**
Interdealer Volume Share		-0.0045			-0.0039		-0.0046			-0.0039
Interdealer Dealer Completeness			-0.0568***		-0.0498***			-0.0565***		-0.0493***
Client Dealer Completeness			-0.0017		-0.0013			-0.0016		-0.0013
Interdealer Market Completeness				-0.0653***	-0.0310				-0.0654***	-0.0315
Client Market Completeness				-0.0721	-0.0762				-0.0642	-0.0685
log(Dealer ‖Inventory‖)	-0.5781***	-0.5796***	-0.4859***	-0.5876	-0.5037***	-0.5822***	-0.5837***	-0.4905***	-0.5910***	-0.5079***
log(‖Net All Dealer Inventory‖)	-0.3034*	-0.3061*	-0.2842*	-0.2964*	-0.2814*	-0.1186	-0.1204	-0.0998	-0.0991	-0.0921
log(All Dealer ‖Inventory‖)	1.2098*	1.2199*	1.4936**	2.0847***	1.9303***					
log(All Long Dealer Inventory)						1.4535**	1.4585**	1.4897***	1.6638***	1.5903***
log(All Short Dealer ‖Inventory‖)						-0.1033	-0.1021	0.0996	0.4458	0.3787
CDS Clearing Eligible	-0.2119	-0.2391	-0.2772	-0.2786	-0.3295	-0.2047	-0.2318	-0.2698	-0.2699	-0.3211
Number of Market Dealers	0.0183	0.021	-0.1367*	-0.3471***	-0.3088**	0.0075	0.0102	-0.1452*	-0.3517***	-0.3142**
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	295,327	295,327	295,327	295,327	295,327	295,327	295,327	295,327	295,327	295,327
Adjusted R^2	4.97%	4.98%	5.04%	5.01%	5.06%	4.99%	4.99	5.06%	5.02%	5.07%

Note: The table presents the results of Equation (15) for the relationship between measures of network completeness, characteristics of dealer inventories, characteristics of the underlying reference entity, and the bid-ask spread of a transaction for a trade between a client and a dealer.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

Table 12: Intermediation Network and Interdealer Bid-Ask Spreads

	Dependent Variable									
	Bid-Ask Spread									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Intercept	15.3158***	14.7630***	16.4074***	21.3942***	21.1012***	14.6619***	14.1297***	15.8241***	21.6436***	21.3904***
Interdealer Volume Share		0.0068***			0.0075***		0.0066***			0.0074***
Interdealer Dealer Completeness			-0.0130		-0.0029			-0.0127		-0.0027
Client Dealer Completeness			-0.0029		-0.0039			-0.0029		-0.0039
Interdealer Market Completeness				-0.0680***	-0.0690***				-0.0665***	-0.0676***
Client Market Completeness				-0.0969**	-0.0875*				-0.0880*	-0.0790
log(Dealer ‖Inventory‖)	-0.0580	-0.0603	-0.0194	-0.0650	-0.0517	-0.0618	-0.0640	-0.0238	-0.0669	-0.0537
log(‖Net All Dealer Inventory‖)	-0.2584**	-0.2572**	-0.2572**	-0.2435**	-0.2430**	-0.1261	-0.1290	-0.1261	-0.1108	-0.1149
log(All Dealer ‖Inventory‖)	0.3985	0.4017	0.4530	1.2907***	1.2984***					
log(All Long Dealer Inventory)						0.9386***	0.9152***	0.9383***	1.0944***	1.0673***
log(All Short Dealer ‖Inventory‖)						-0.5365	-0.5082	-0.4919	0.0631	0.0982
CDS Clearing Eligible	0.9119***	0.9477***	0.8966***	0.8139***	0.8553***	0.9119***	0.9469***	0.8973***	0.8207***	0.8616***
Number of Market Dealers	-0.1471***	-0.1506***	-0.1830***	-0.5551***	-0.5677***	-0.1556***	-0.1587***	-0.1905***	-0.5500***	-0.5625***
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312	1,053,312
Adjusted R^2	9.40%	9.41%	9.41%	9.46%	9.48%	9.41%	9.43%	9.42%	9.47%	9.49%

Note: The table presents the results of the Equation (16) for the relationship between measures of network completeness, characteristics of dealer inventories, characteristics of the underlying reference entity, and the bid-ask spread of a transaction for a trade between dealers.

Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

5 Conclusions

Theory predicts that the density of intermediation trade networks affect the liquidity of over-the-counter markets. In this paper, we empirically examine this prediction by testing whether several hypotheses of this literature are supported empirically, using data from the single-name CDS market. Our results indicate a strong relationship between the market's intermediation network and liquidity provision by dealers, both individually and collectively, as seen through trade volume, market participation, and inventory management. We find a significant relationship between the completeness of the intermediation network and the cost of trade; i.e., the cost of executing a trade as well as the bid-ask spread, with some differentiation between the interdealer and the dealer-to-client market segments.

At the level of intermediation networks for individual dealers, our results are generally consistent with theoretical predictions, as well as the previous empirical literature of debt markets. However, we do find some differences with the previous studies. For example, we find that dealer execution costs are driven largely by a dealer's transactions with clients, while bid-ask spreads are primarily driven by the ability of the dealer to trade with other dealers, but not necessarily with clients. We also find that a dealer's interdealer execution cost declines as the completeness of the dealer's individual dealer-to-client network increases, but that, perhaps surprisingly, this execution cost is not related to the completeness of the dealer's relationships with other dealers. In addition, the bid-ask spread a dealer receives on dealer-to-client trades declines as the completeness of the dealer's network with other dealers increases, while its interdealer bid-ask spread is not related to the trade network it has with other dealers.

Our market-level findings highlight several differences in how a market vs. an individual's intermediation network impacts liquidity and question theoretical predictions that more complete markets always lower execution costs and narrow bid-ask spreads. One such example is that a dealer's execution cost when trading with other dealers increases – rather than decreases – as the completeness of the dealer-to-client network at the market-level increases. This finding is suggestive of the relationship between interdealer trade and the demand to intermediate inventory. As the dealer-to-client network becomes more complete, a dealer's need to intermediate inventory within the interdealer network declines, and dealers may charge higher execution costs to one another.

Since our study focuses on the single-name CDS markets, during a period when several regulatory reforms were enacted, our results help shed light on the importance of trading relationships in maintaining market liquidity. We find several shifts in dealer behavior during this period, as interdealer trade and dealer participation declined, and inventory management tightened. All these shifts are consistent with a decline in market liquidity. Although the focus of our paper is on the consequences of network changes – and specifically network completeness – on liquidity, rather than on the relationship between regulations and changes in intermediation networks, our paper does highlight the need for policymakers to consider how regulations lead to changes in counterparty relationships.

Finally, the network measures that we use can also be used to study the consequence of regulations or the failure of an intermediary. For example, consider regulations for trading index CDS contracts which were mandated to clear centrally and trade on swap execution facilities beginning in 2013. These two regulations reduce collateral for centrally cleared transactions and centralize trade. Given theoretical predictions on the effect of these regulations, our measures and methods could provide empirical insight into how intermediation evolved and impacted liquidity. More importantly, whether the benefits of these mandates outweigh the costs remains an open question.

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Table A.1: Variable Dictionary

CDS $\text{Spread}_{j,t}$	Markit spread for reference entity j at time period t
ΔCDS $\text{Spread}_{j,t}$	Change in Markit spread for reference entity j, between time period t and $t-1$
CDS Transaction $\text{Spread}_{i,j,t}$	CDS spread of transaction of firms i on reference entity j at time period t
Recovery $\text{Rate}_{j,t}$	Markit estimated recovery rate for reference entity j at time period t
Index λ^{C}_t	Total dealer-to-client volume of index CDS at time period t
Bond $\lambda_{j,t}$	Total volume of underlying bond of reference entity j at time period t
$\mathbb{1}^{\text{Clearable}}_{j,t}$	Eligible to clear indicator variable for reference entity j at time period t capturing clearing fixed effects
$\mathbb{1}^{\mathrm{M}}$	Month indicator variables capturing seasonality fixed effects
$\mathbb{1}^{\mathrm{M/Y}}$	Year-month indicator variables capturing time fixed effects
$\lambda^{\mathrm{C}}_{j,t}$	Client CDS volume for reference entity j at time period t
$\lambda^{\mathrm{D}}_{i,j}$	Interdealer CDS volume for reference entity j at time period t
$\lambda_{j,t}$	Total CDS volume for reference entity j at time period t
$\lambda^{\mathrm{D}}_{j,t}/\lambda j,t$	Share of Interdealer CDS volume over total CDS volume for reference entity j at time period t
$\mathcal{M}_{j,t}$	Set of market participants for reference entity j at time period t
$\mathcal{D}_{j,t}$	Set of market dealers for reference entity j at time period t
$\mathcal{C}_{j,t}$	Set of market clients for reference entity j at time period t
$x_{i,j,t}$	Absolute value of net inventory of individual dealer i for reference entity j at time period t
$\mathrm{X}_{j,t}$	Absolute value of net aggregate inventory for reference entity j during time period t
$\mathrm{K}^{\mathrm{D}}_{j,t}$	Market's network completeness of interdealer network of reference entity j at time period t
$\mathrm{K}^{\mathrm{C}}_{j,t}$	Market's network completeness of dealer-to-client network of reference entity j at time period t
$\mathrm{k}^{\mathrm{D}}_{j,t}$	Dealer's network completeness with other dealers of reference entity j at time period t
$\mathrm{k}^{\mathrm{C}}_{j,t}$	Dealer's network completeness with clients of reference entity j at time period t
$\mu^{\mathrm{C}}_{i,j,t}$	Execution cost relative to Markit spread for dealer-to-client transactions for dealer i, reference entity j during time period t
$\mu^{\mathrm{D}}_{i,j,t}$	Execution cost relative to Markit spread for interdealer transactions for dealer i, reference entity j at time period t
$\gamma^{\mathrm{C}}_{i,j,t}$	Bid-ask spread relative to Markit spread for dealer-to-client transactions for dealer i, reference entity j at time period t
$\gamma^{\mathrm{D}}_{i,j,t}$	Bid-ask spread relative to Markit spread for interdealer transactions for dealer i, reference entity j at time period t
$\log(\text{Dealer } \lVert\text{Inventory}\rVert_{i,j,t})$	Logarithm of the absolute value of the inventory of individual dealer i for reference entity j at time period t
$\log(\lVert\text{Net All Dealer Inventory}\rVert_{j,t})$	Logarithm of the absolute value of aggregate, net, inventory for reference entity j at time period t
$\log(\text{All Dealer } \lVert\text{Inventory}\rVert_{j,t})$	Logarithm of the sum of the absolute values of dealer inventories for reference entity j at time period t
$\log(\text{All Dealer Long Inventory}_{j,t})$	Logarithm of the sum of the inventories of dealers that are long CDS contracts for reference entity j at time period t
$\log(\text{All Dealer Short } \lVert\text{Inventory}\rVert_{j,t})$	Logarithm of the sum of absolute value of the inventories of dealers that are short CDS contracts for reference entity j at time period t

Note: List and definition of all variables used in regression models.
Source: Authors' creation.