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

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June 26, 2021

Abstract

A growing theoretical literature predicts that over-the-counter intermediation networks affect market liquidity. Using supervisory data for the U.S. single-name credit default swap market, we empirically evaluate several predictions of this literature. We find that an intermediation network's density relates to the liquidity provision of dealers, both individually and collectively, as seen through trade volumes and inventory management. Further, we find a relationship between network density and the cost of trade, measured by execution costs and bid-ask spreads, though we note that the effects differ across the segmented trade channels of dealers and clients, and those between dealers.

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

[†]We would like to thank Jill Cetina, Richard Haynes, Diana Iercosan, Ayla Kayhan, Dasol Kim, Robin Lumsdaine, David McArthur, Bruce Mizrach, Esen Onur, Chay Ornthanalai (discussant), Carlos Ramirez, Christer Rydberg (discussant), Stacey Schreft, Zhaogang Song, Alireza Tahbaz-Salehi, Anjan Thakor, H. Peyton Young, Jingyu Zhang, Haoxiang Zhu, John Zitko and seminar participants at the Office of Financial Research, McCombs School of Business, Federal Reserve Board, Financial Industry Regulatory Authority, Midwest Finance Association Annual Meeting, the U.S. Commodity Futures Trading Commission, the Universidad Adolfo Ibañez, the Midwest Finance Association Meeting, the Financial Market & Corporate Governance Conference, and the World Federation of Exchanges Clearing and Derivatives Conference, for comments and suggestions. This paper was previously distributed and presented as "Market-Making Costs and Liquidity: Evidence from CDS Markets". Any errors are our own. Views and opinions expressed are those of the authors and do not necessarily represent official positions or policy of the OFR or the U.S. Department of the Treasury.

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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); Chang and Zhang (2019)).

These models illustrate how relationships influence liquidity by providing dealers with trading opportunities and easing the difficulty of rebalancing portfolios. Changes to intermediation networks which reduce relationship density, due to, for example, 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 eliminating trading relationships (Elliott (2015)), can decrease market liquidity.[1] While the consequences of an individual dealer's network have been examined (Di Maggio et al. (2017); Hollifield et al. (2017); Li and Schürhoff (2019)), little empirical work has explored the broader implications of the intermediation network on market 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 previous empirical studies that focus on individual market participants, we consider intermediation networks at both the individual participant level and market level. In addition, we separate the network effects along the two traditional tiers, 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. This period is particularly interesting due to many changes in the regulation of CDS markets.[3] With these data, we reconstruct the

[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.

[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

intermediation network of market participants across hundreds of assets. Over the sample period, we find a series of significant changes to intermediation networks: dealer participation and network density decline, and dealers change the way they manage inventories. These changes provide ample 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 at the level of the entire 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) the cost of trade through execution costs and 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 6 percent in dealer-to-client volume. 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 27 percent.

Beyond market volume, we also consider how network completeness relates to measures of risk-bearing capacity for dealers, both individually and in aggregate. We measure risk-bearing capacity through the size of dealer inventories. The literature suggests that the difficulty to offset inventory affects the demand for holding inventory on a dealer's balance sheet and the entry or exit of dealers (Carapella and Monnet (2020)). The literature predicts a positive relationship between both the completeness of dealer and market networks, and the size of a dealer's inventory: counter-

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.

party 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 suggest that dealers with more complete individual networks are willing bear more risk, reflected in higher inventories, while more complete markets allow more efficient allocation of inventory to clients, reducing individual dealer inventories.

Beyond dealer and market inventory, completeness of intermediation networks relates to 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 in the single-name CDS markets. However, in contrast to other papers, we can 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 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 with 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 manage inventory. As the dealer-to-client network becomes more complete, a dealer's need to manage inventory using the interdealer network declines and dealers charge higher execution costs to one another.

Our paper contributes to the literature in several ways. First, we validate several predictions in the literature regarding the relationship between market structure and dealer behavior in an over-the-counter market. We also find that the market-wide network between market participants relates to the liquidity provision of dealers, both individually and collectively, as seen through trade volumes and inventory management. We also document the relationship between execution costs and bid-ask spreads and intermediation. We find that the effects between interconnectedness and execution costs or bid-ask spreads differ for trades between dealers and clients and trades between dealers.

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 these 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 CDS market, the OTC market setting of our study, has a rich literature examining their function and pricing. Unlike empirical network literature on corporate debt markets, the CDS market exhibits lower search frictions and synthetic access to otherwise unavailable assets (Oehmke and Zawadowski (2015)). Clients in the CDS markets may trade to hedge risk, to speculate, or to strategically cross-market arbitrage differences in liquidity or price (Oehmke and Zawadowski (2017)).

As a result, the liquidity provision of a CDS dealer requires controlling for several factors. Similar to traditional market makers in equity markets, Shachar (2012) finds that the ability of a dealer to control their clients' order imbalances is central to a dealer's willingness to intermediate and the prices which they offer. However, the risk associated with the sudden jump-to-default, poses additional dealer inventory considerations. Siriwardane (2019) finds that liquidity spillover effects in CDS bid-ask spreads after the 2011 Japanese earthquake and tsunami. Additionally, the longer-term obligations of CDS contracts require dealers to control for counterparty risk, where a party to a CDS transaction might default at the same time that the underlying reference entity also defaults. Du et al. (2016) 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.

Similar to other OTC markets, CDS trade is segmented into dealer-to-client trades, typically driven by clients, and interdealer trades that are primarily used to intermediate risk. Collin-Dufresne et al. (2020) study this segmentation, and find that, for index CDS contracts traded on swap exchange facilities, the price impact is different depending on which segment a transaction takes place in. Specifically, they find that dealer-to-client transactions have a higher average price impact, and that dealer-to-client transactions Granger-cause interdealer transactions, consistent with the interdealer market being used to manage inventory risk. In a related paper, Riggs et al. (2020) focus 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 dealer-to-collateral relationships are important empirical determinants of customers' choice of trading mechanism and dealers' liquidity provision.

Though the network structure of the CDS markets helps diversify much of the risk, D'Errico et al. (2018) illustrates that the intermediation between hedge funds, that sell risk, and asset managers that purchase risk, results in a large portion of the risk ending up in a few leading risk buyers. Eisfeldt et al. (2018) assess the implications of this network transmission channel on how dealers structure their intermediation of CDS counterparty risk through a theoretical model, which they use to study the impact of the potential exit of a key intermediary. In contrast, our paper focuses on the relationship between counterparty networks, reference entity risk intermediation, 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 provides summary statistics on how CDS intermediation networks evolved over the period we study. Section 3 discusses the theoretical hypotheses 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 between 2010 and 2016. Having access to every transaction and weekly positions of every participant allows us to construct trade relationship networks between market participants, including those 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 35 percent of transactions include the credit spread at which the transaction took place. The total number of U.S. CDS reference entities with senior-tier debt is 1032, while the total number of dealers is 32.[6] 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 TIW and Markit datasets to implicitly determine the date that CDS contracts on a reference entity become eligible for central clearing; we set the date to the first

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

[6]Dealers are identified in the TIW data by DTCC, as dealers are responsible for submitting transaction data.

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.

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.[7] In addition, we determine whether a transaction is dealer- or client-initiated, based on which side paid the implied bid-ask spread.[8]

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. TRACE allows for map CDS contracts to the underlying corporate bonds and to calculate the volume of trading for the underlying corporate bond. Unlike the TIW dataset, not all counterparties are identifiable in TRACE, which requiring volumes be aggregated at the market level.

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.[9] Table 1 presents summary statistics for the single-name CDS market during this period, with variables averaged monthly and split by year. We note that the average number of dealers and average dealer gross

[7] 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) define the execution cost of a transaction using the CDS par spread relative to the end-of-day CDS consensus par spread from Markit.

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

[9] 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, 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. (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.

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

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)
# 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)

Note: The table presents average monthly summary statistics for the volume, number of trades, dealer inventories, and number of dealers and clients per reference entity, by year. Volume, net notional, and gross notional reported in $ millions by CDS reference entity.
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 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.

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

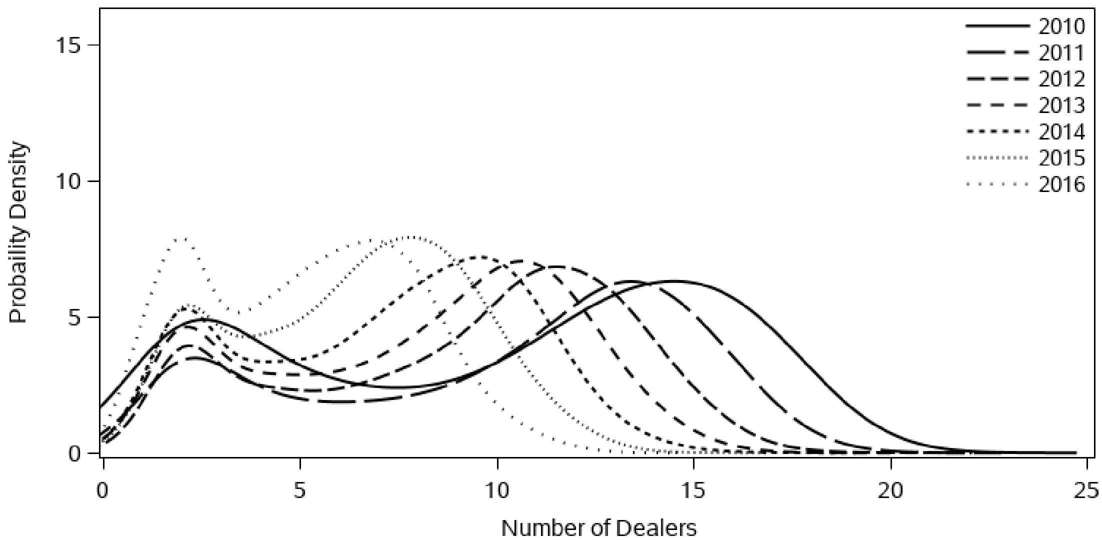
Note: The CDS spread is the annual average and (standard deviation) Markit CDS spread, measured in basis points across the CDS reference entities. The bid-ask spread is calculated by finding the distance that a transaction occurs at, relative to the daily Markit CDS spread and is presented as a percentage of the daily Markit CDS spread. The table presents average and (standard deviation) 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 implied bid-ask spread. Finally, the last three rows 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.

1.3 Changes in Intermediation Behavior

Beyond the clear decline in CDS market volume throughout our study seen in Tables 1 and 2, we find that the intermediation behavior of dealers changed drastically as well. We demonstrate these changes in three ways in this section, and in the next section, we construct measures that capture these changes and link them to the market provision of liquidity by intermediaries, both individually and collectively.

First, similar to the results in Table 1, 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.[10]

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

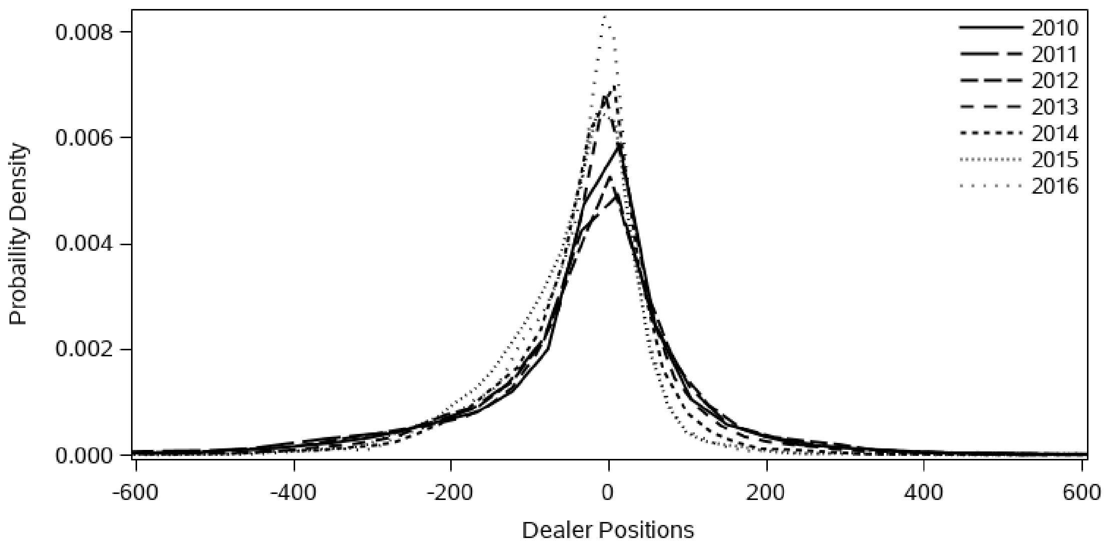
Second, we find changes in the level of inventory dealers are willing to maintain. Figure 2 shows the distribution of dealer inventories for each year in our data – the inventories are calculated monthly for every single-name reference entity in the data. For each reference entity and each month, the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

Finally, Figure 3 illustrates changes in inventory management practices by the single-name CDS dealers. The left panel shows dealer week-over-week change in positions grouped by periods.[11] In line with results in the microstructure literature for other markets – see Hansch et al. (1998) – the figure shows that dealers tend to decrease the size of their inventories when they deviate from a net zero position for every year in the data.

[10]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 declining demand for single-name CDS – this feature is endogenous, and consistent with an increase, in the cost of intermediation.

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

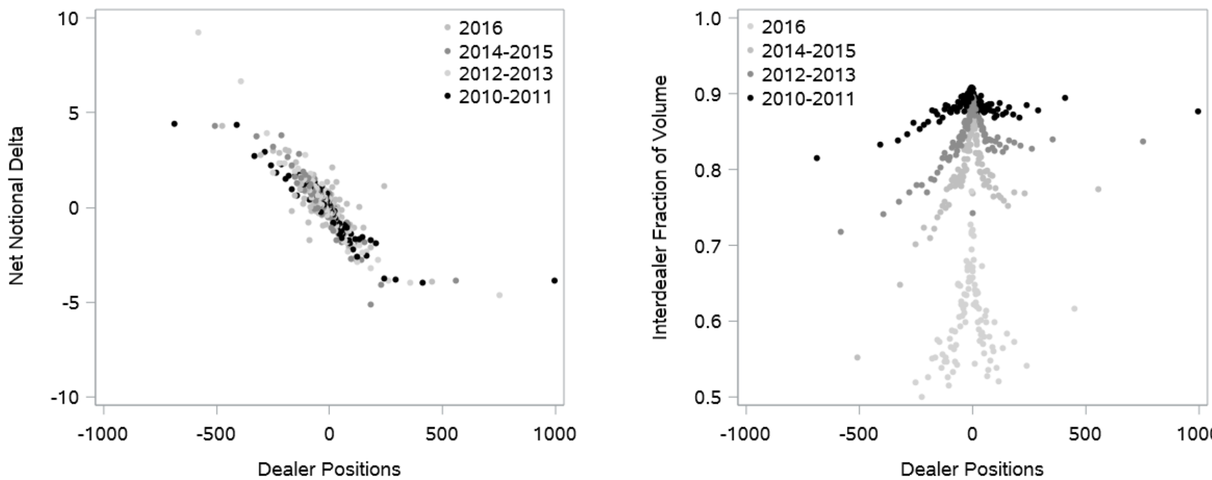
Figure 2: Dealer Net Notional Inventory



Note: The plot presents the probability density function of weekly dealer notional positions (in $ millions), 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.

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 increasingly difficult, particularly as a function of the level of a dealer's inventory (Wang and Zhong (2020)).

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 inventory management practices in the single-name CDS market. Plot (a) shows week-over-week changes in dealer inventory vs. the previous week's inventory (in $ millions). Each point presents the average weekly inventory change grouped by years and centile of the previous week's 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 (in $ millions). Each point presents the average weekly fraction of interdealer trade, done by dealers, grouped by years and centile of the previous week's 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.

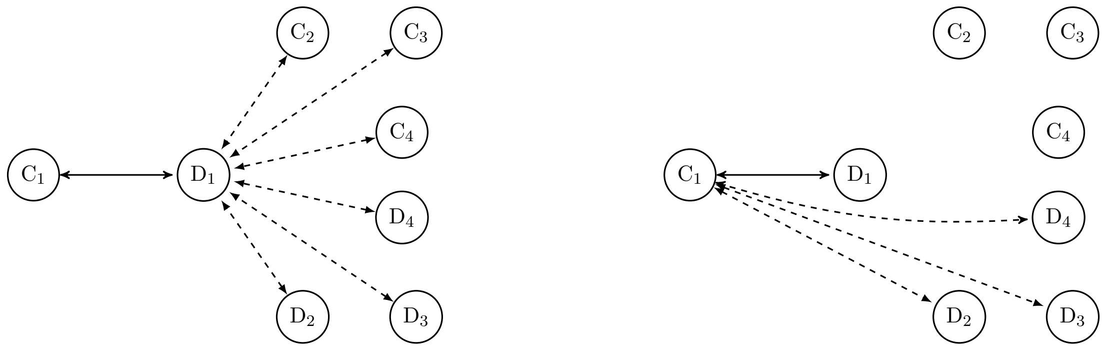
2 Intermediation Network Measures

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 can reduce the underlying risk of the position they assume by offsetting the risk through interdealer trade or contraposition clients.[12] 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

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

to, or further from, her preferred inventory level, is likely to influence the execution cost and the bid-ask spread offered 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.

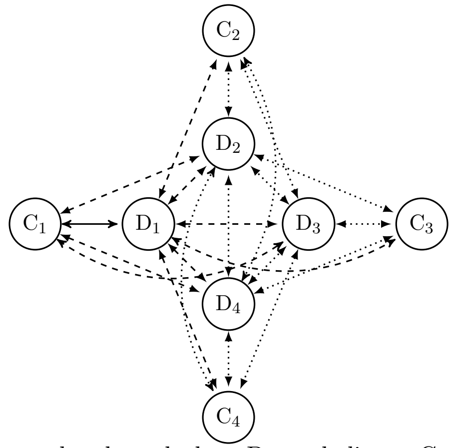
The ease of offsetting the risk associated with holding inventory depends on a dealer's relationships with other market participants, with whom she has prearranged trading agreements (Siriwardane (2019)). These relationships are illustrated by the dashed lines in Figure 4a. The more market participants a dealer or client has agreements with, the higher the likelihood it will transact at a lower execution cost. In setting prices, and to attract the transaction, the dealer must consider the client's potential other options, as shown in Figure 4b.

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 dealer D_1 and client C_1 have their own trading options, which 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 market participation.

2.1 Network Measures

To measure intermediation in an OTC market, we introduce measures that quantify relationships between dealers and relationships between dealers and clients. We illustrate these measures

Figure 5: Market Intermediation Network



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

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.[13]

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.

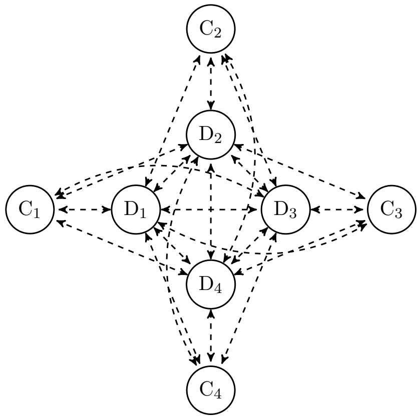
We measure the degree of counterparty relationships for a market participant i by translating the trading network into an adjacency matrix A, where a_{ij} is equal to 1 if parties i and j are connected and zero otherwise. The number of relationships for participant i is given by

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

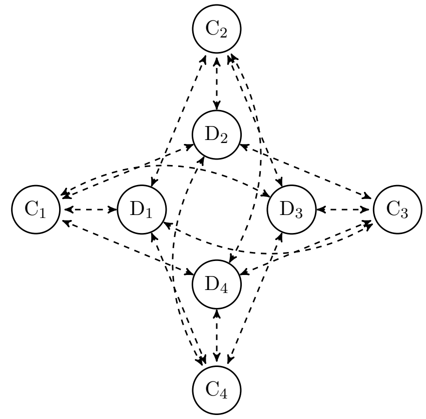
where the sum is over all market participants in a particular CDS market, $\mathcal{M}$.

[13]The literature considers additional measures, such as eigenvector centrality, to measure the strength of the relationships in a network. Compared to the measures in the literature, our measures require more detailed information and have the potential to differentiate the impact of different relationships in ways that measures in the literature cannot. Given the detailed information available in our data, and the difficulty to simultaneously apply the measures in the literature to multiple networks – e.g., the interdealer and dealer-to-client networks – we have not considered using the measures in the literature.

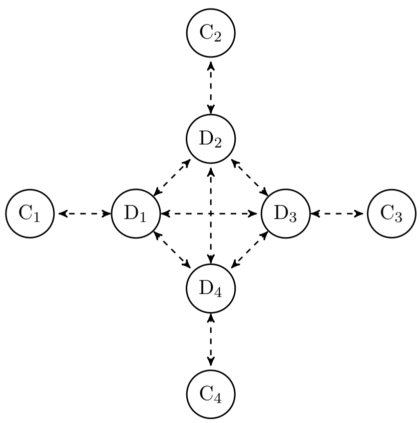
Figure 6: OTC Network Completeness



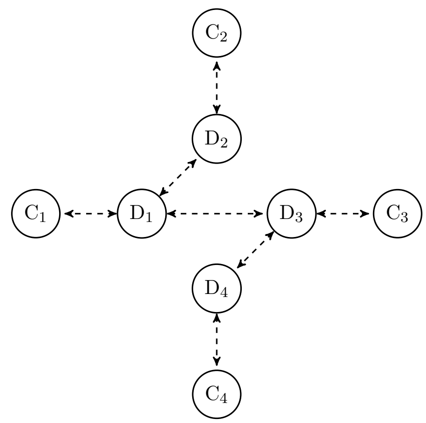
(a) Complete Network



(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 dashed 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.

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 of $\mathcal{M}$: 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 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 Measuring Intermediation Network Effects

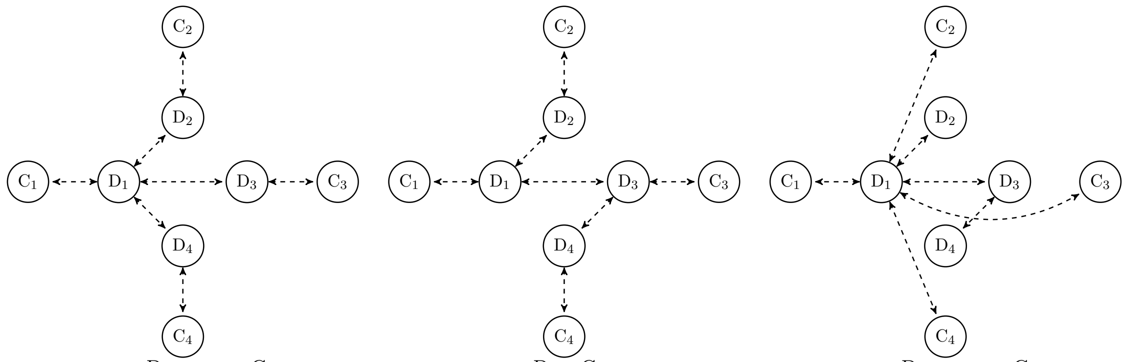
A dealer and market's network can each have different effects on liquidity. To demonstrate their implications and how each of our measures can help us interpret variations in each network we review two examples that highlight direct and indirect effects.

First, we consider the networks in Figure 7. The number of relationships between dealers and the number of connections between clients and dealers is the same for each network in Figure 7, but the networks are different. We consider Figure 7b as the base case, with a trade network where no dealer is connected to all other dealers or all clients, and the client dealer completeness and the interdealer dealer completeness are equal to 25 percent and 67 percent respectively for dealer D_1. In this network, dealers D_1 and D_3 have a privileged position with respect to dealers D_2 and D_4 due to their higher interdealer connectivity.

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, for dealer D_1, the client-dealer completeness and the interdealer completeness are equal to 25 percent and 100 percent respectively. This is an example of a network where dealer D_1 has more options to rebalance her 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

Figure 7: OTC Network and Dealer Liquidity



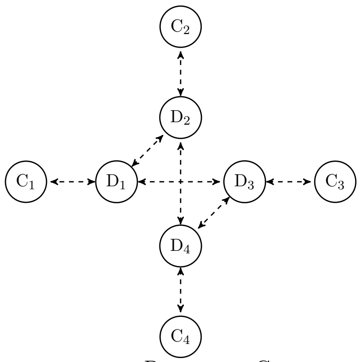
(a) High k_1^D, Low k_1^C for D_1 Network **(b)** Low k_1^D, k_1^C for D_1 Network **(c)** Low k_1^D, High k_1^C for D_1 Network

Note: Figures (a)-(c) present example trading networks where dealers, D_i, and clients, C_j, are depicted as nodes, and dashed 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.

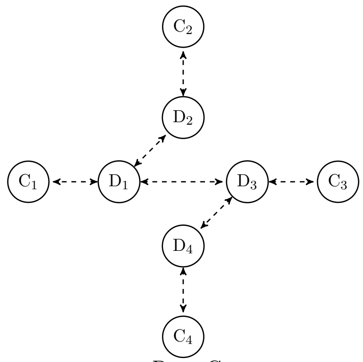
are not. For dealer D_1, the completeness of the client-dealer network is equal to 100 percent, while the completeness of her interdealer network is equal to 67 percent. Similar to the previous case, in this trade network, the bargaining power of dealer D_1 is potentially larger relative to the other dealers. However, her bargaining power is based on her relationships with clients rather than other dealers, allowing her to directly intermediate CDS inventory with clients.

An additional consideration, beyond dealer-specific effects, is the effect of these intermediation networks on market-wide. For example, while more relationships for dealer D_1 are likely to improve her provision of liquidity, what this does for the provision of liquidity of the other dealers is not clear. To illustrate that these indirect effects may affect market liquidity consider the example networks in Figure 8. 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 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 dealer 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.

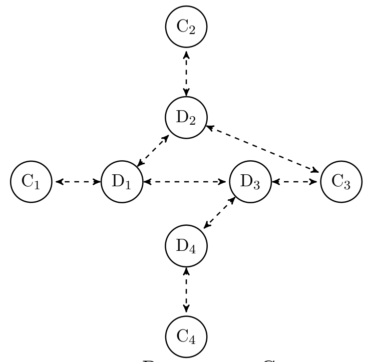
Figure 8: OTC Network and Market Liquidity



(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 dashed 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 dealer D_1's interdealer relationships remain the same as Figure 8b but a new interdealer relationship exists between dealers D_2 and D_4. The result is that 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 network change concerning dealer D_1 has no clear direct effect on her liquidity. Additionally, it is not clear what this change will do to the new equilibrium rebalancing of dealer D_1's inventory relative to Figure 8b, and, whether she should expect to see a decrease or increase in liquidity due to this indirect change to her network. It may be beneficial, as dealer D_1 does have an interdealer relationship with dealer D_2, which could increase her intermediation opportunities if dealer D_2 sees more volume. Dealer D_1 may also be worse off, as dealer D_2 can offset positions with another dealer now and force dealer D_1 to offer more competitive trade costs.

Figure 8c is a trade network where dealer 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. It may be beneficial to dealer D_1 since she does have an interdealer relationship with dealer D_2, which could increase her intermediations opportunities if dealer D_2 gets more volume. On the other hand, she could be worse off as dealer D_2 could directly offset positions between clients C_2 and C_3, and no longer need dealer D_1 to intermediate trade.

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.

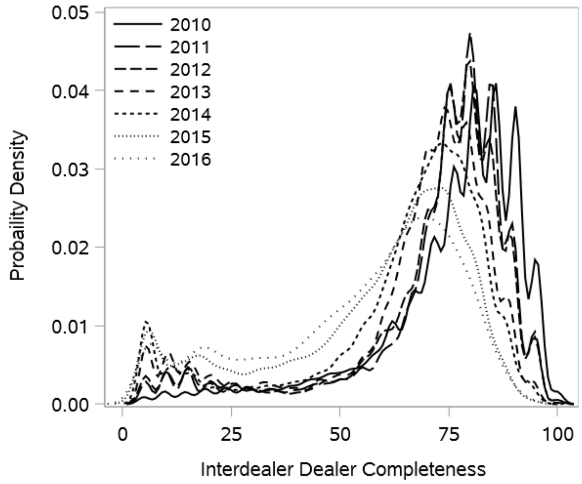
2.3 Intermediation Network Statistics

Measuring whether trading relationships exist is not straightforward as interfirm International Swaps and Derivatives Association (ISDA) contracts, which govern whether two firms can transact in a particular security, are not publicly available. While unable to see the ISDA contracts, the supervisory dataset does provide an imperfect but conservative substitute through the counterparty-level positions and transactions. We use this information to measure the network of relationships between dealers and clients.

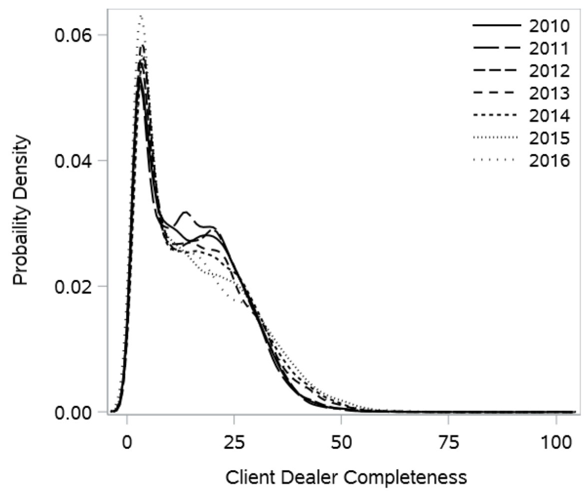
To compute the completeness measures we use a combination of the CDS positions and transactions. We use positions to define the existence of a relationship between firms on a particular CDS reference entity, and transactions to indicate whether firms are active participants in this market. Since many single-name CDS contracts transact relatively infrequently, we calculate our measures weekly using a five-week rolling window of transactions to define active participants. Additionally, to ensure significant variation in trading volume and networks, we limit the data throughout our study to reference entities with at least four dealers with non-zero positions during the sample period.

Figure 9 presents annual density distributions for dealer-level network measures. While the shape of the distribution of both completeness measures is consistent across time, the mean interdealer dealer completeness measure declines. We don't observe the same decline in the dealer-to-client network measures. We note that the distribution of interdealer network measures is bi-modal, left-skewed. This shape suggests that most dealers have relatively complete relationships with other

Figure 9: Dealer Network Completeness Distribution



(a) Interdealer Dealer Completeness



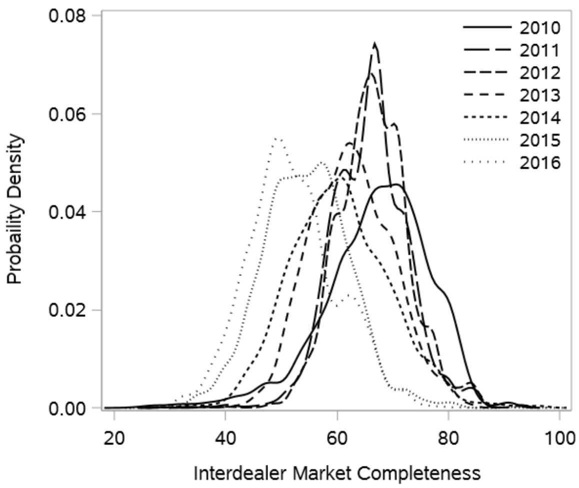
(b) Client Dealer Completeness

Note: Plots (a) and (b) present the probability density function of interdealer and client dealer completeness, by year, across our sample of U.S. single-name CDS reference entity markets. The overlay highlights that interdealer interconnectednesss shifts over the sample period, with more recent years showing a decline in interdealer trading relationships at the participant level.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

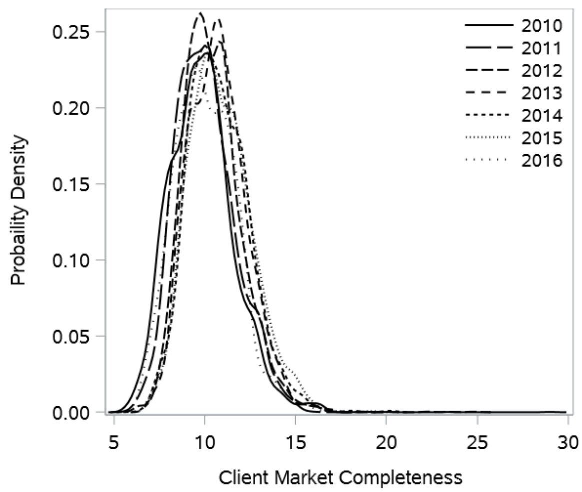
dealers, while a few dealers use the market to offset positions for a single client or hedge their risks. The distribution of the dealer-to-client network measures is right-skewed, suggesting that most dealers intermediate for a few – or possibly only one – client.

Figure 10 presents the annual density distributions for market-level network measures. Similar to the dealer-level completeness distributions, the market-level measures reveal that the completeness of the interdealer network has declined, and the dealer-to-client network has remained steady over the sample. We find that dealers, on average, are much more well-connected to one another than they are to clients, which is consistent with the core-periphery structure typically seen in OTC markets.

Figure 10: Market Network Completeness Distribution



(a) Interdealer Market Completeness



(b) Client Market Completeness

Note: Plots (a) and (b) present the probability density function of interdealer and client market completeness, by year, across our sample of U.S. single-name CDS reference entity markets. The overlay highlights that interdealer interconnectedness shifts over the sample period, with more recent years showing a decline in interdealer trading relationships at the 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 factors such as search costs, transaction costs between dealers or between dealers and clients, and dealer costs of holding 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. Nonetheless, regardless of the cause, the completeness of an intermediation network provides an observable measure of a market's ability to support efficient trade. In this section, we outline five hypotheses on the relationships between the measures of OTC network completeness – at both the individual dealer and aggregate market levels – and measures of liquidity: trading volume, dealer inventory, and trade costs.

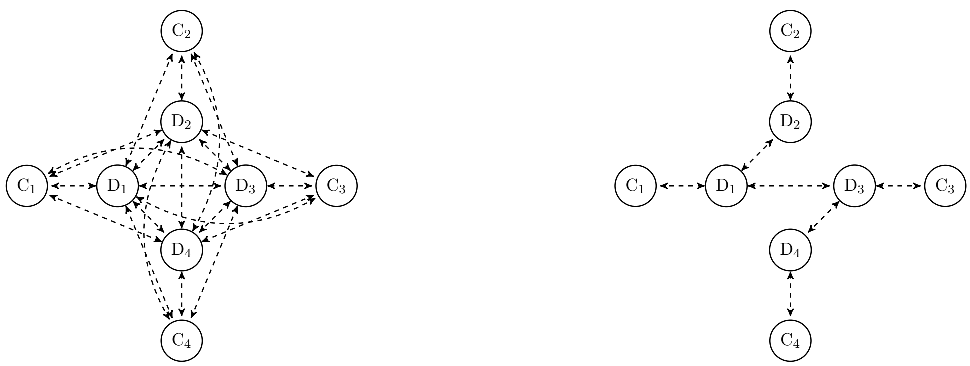
3.1 Intermediation Network & Volume

Our first hypothesis links trading volume to the degree of completeness in market relationships.

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 to find a counterparty with whom one can trade. The hypothesis postulates that this ease translates to higher trade volume. We expect that if we were given two networks, as illustrated in Figure 11, we would expect to see higher volumes in network (a) over (b) due to the higher relative market completeness, all else equal.

Figure 11: Market Completeness and Volume



(a) High K^D, High K^C **(b)** Low K^D, Low K^C

Note: The figure presents two trading networks, where dealers, D_i, and clients, C_j, are nodes, and dashed links represent trade relationships. Market network (a) has a higher density of interdealer and dealer-to-client relationships than market network (b), as measured by K^D and K^C completeness. Network (a) has a $K^D = 1$ and $K^C = 1$, where network (b) has a $K^D = 1/2$ and $K^C = 1/4$.
Source: Authors' creation.

H1 is consistent with findings in Babus and Kondor (2018) which suggest that increased completeness of the network 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 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)).

3.2 Intermediation Network & Dealer Inventories

Oehmke and Zawadowski (2017) show that the transaction volume reflects the demand for both hedging and speculation. In contrast with the corporate debt market – see Hollifield et al. (2017); Di Maggio et al. (2017); Li and Schürhoff (2019) – dealers in derivative markets are not supply constrained; i.e., they don't need to hold inventory to supply liquidity clients wishing to purchase. Thus, trading volumes reflect the willingness of dealers to supply liquidity to their clients. This willingness depends on the ability of dealers to manage their market risk and balance sheet space. Our next two hypotheses link dealer behavior – specifically dealer inventories – and measures of completeness, first at the individual dealer level and then at the aggregate market level.

H2: *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.*

H2 focuses on individual dealer inventory management. Similar to much of the theoretical literature, H2 suggests that a dealer with a more complete dealer-to-client and interdealer network is able to bear more risk. Neklyudov (2019) finds that dealers with better search technology, i.e. dealers that are better connected, find 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)).

H3: *The completeness of a market's intermediation network, controlling for the completeness of the intermediation network of individual dealers, is:*

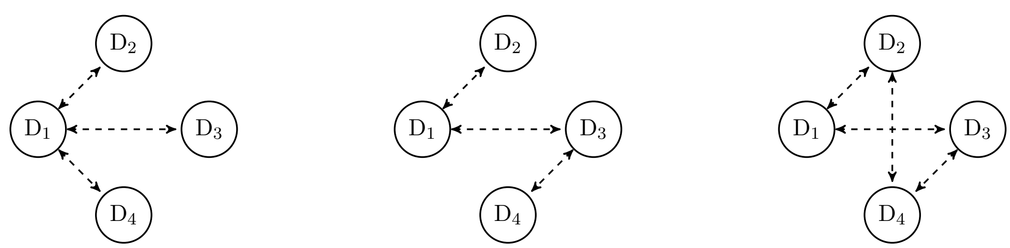
- *a. positively related to the risk-bearing capacity of individual dealers; i.e., their net inventory;*
- *b. positively related to the gross risk-bearing capacity of all dealers; i.e., the sum of the absolute value of dealer inventories.*

In contrast to the previous hypothesis, H3 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 hold larger inventories because they can cheaply find counterparties to offload their inventory when needed. 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, for example by buying an asset from a seller, 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 the distribution of dealer inventory. The intuition behind Neklyudov (2019) suggests a similar outcome though the result depends on inventory risk, rather than interdealer coordination concerns. Gofman (2011) finds that under the bilateral bargaining frictions of OTC markets, efficient allocation can occur only when the trading network is complete.

To illustrate these two hypotheses, consider just the interdealer networks (a), (b), and (c) in Figure 12 from the perspective of dealer D_1.[14] Each of these three networks represents variation in the level of dealer and market completeness relative to each other. Hypothesis H2 suggests that network (a) provides dealer D_1 more risk-bearing capacity than network (b) given the high level of completeness of her interdealer network, k_1^D. Hypothesis H3(a) suggests that network (c) provides dealer D_1 more risk-bearing capacity than network (b) given the high level of the completeness of the interdealer market network, K^D.

Figure 12: Dealer & Market Completeness and Dealer Inventories



(a) High k_1^D, Low K^D **(b)** Low k_1^D, Low K^D **(c)** Low k_1^D, High K^D

Note: The figure presents an interdealer trading network, where dealers, D_i, are nodes and dashed links represent the trade relationships. Interdealer network (a) has a higher density of dealer completeness for D_1 than interdealer network (b) and (c), with $k_1^D = 1$ for (a) and $k_1^D = 2/3$ for (b) and (c). Interdealer network (c) has a higher density of market completeness than interdealer network (a) and (b), with $K^D = 2/3$ for (c) and $K^D = 1/2$ for (a) and (b). *Source*: Authors' creation.

To illustrate hypothesis H3(b) consider the interdealer networks (b) and (c), and the risk-bearing capacity of all dealers, D_{1-4}, in the market. H3(b) suggests that network (c) provides a higher degree of risk-bearing capacity across all dealers than network (b) given the high level of

[14]The intuition is generally applicable to the dealer-to-client portion of the market as well.

interdealer market completeness, K^D.

3.3 Intermediation Network & Trade Costs

Our final two hypotheses link measures of transaction costs and measures of market completeness.

H4: *The completeness of a dealer's intermediation network is negatively related to the execution cost and the bid-ask spread faced by individual dealers.*

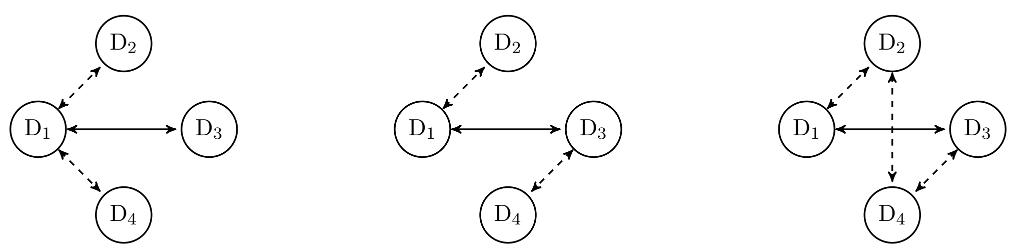
This hypothesis focuses on the completeness of the network of an individual dealer and is similar to propositions on dealer centrality found in the literature. The intuition is that a dealer with a more complete network is able to trade at lower execution costs and consequently can offer better bid-ask spreads to its counterparties. Babus and Kondor (2018) predict that this feature is due to clients being less concerned about adverse selection from dealers, and from well-connected dealers being able to learn prices better than other dealers. These predictions are consistent with the empirical findings in Hollifield et al. (2017) and Di Maggio et al. (2017) for the case of the corporate bond market. However, both of these empirical papers are limited in that they only observe interdealer networks when assessing trade costs. As a result, it is unclear how important each part of a dealer's network is in influencing the cost of a trade. Our data allow us to separate this influence by measuring completeness with respect to both the client and the interdealer networks of individual dealers.

H5: *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, H5 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, a determinant of a dealer's trading cost, besides her centrality, is the centrality of her counterparties. This theoretical result is supported 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 papers are limited to observation of only the interdealer network, it is not clear whether the results hold after controlling for both the dealer's interdealer and dealer-to-client networks. Our data allow us to separate the two, and help us determine the relative bargaining power of dealers with respect to the entire market, and the impact on the equilibrium cost of a trade.

To illustrate the two hypotheses, consider the interdealer networks (a), (b), and (c) in Figure 13 from the perspective of dealer D_1. These networks are similar to the networks in Figure 12. Rather than just relationships, we observe an actual trade between dealers D_1 and D_3. Hypothesis H4 suggests that the average trade of cost in network (a) is lower for dealer D_1 than the same trade in network (b) given the high level of interdealer dealer completeness, k_1^D, holding all else equal. Similarly, if dealer D_1 had a higher level of client-dealer completeness, k^C, she would have lower trade costs.

Figure 13: Dealer & Market Completeness and Trade Costs



(a) High k_1^D, Low K^D **(b)** Low k_1^D, Low K^D **(c)** Low k_1^D, High K^D

Note: The figure presents three interdealer trading networks, where dealers, D_i, are nodes, and dashed links represent trade relationships. The solid link represents a trade between dealers D_1 and D_3. Interdealer network (a) has a higher density of dealer completeness for D_1 than interdealer network (b) and (c), with $k_1^D = 1$ for (a) and $k_1^D = 2/3$ for (b) and (c). Interdealer network (c) has a higher density of market completeness than interdealer network (a) and (b), with $K^D = 2/3$ for (c) and $K^D = 1/2$ for (a) and (b).
Source: Authors' creation.

To illustrate hypothesis H5 consider the interdealer networks (b) and (c). Hypothesis H5 suggests that the cost of trade of dealer D_1 with dealer D_3 is lower in network (c) relative to the cost in network (b), given the high level of interdealer market completeness, K^D, holding all else equal. H5 also suggests that if dealer-client market completeness K^C were higher, the trade cost for dealer D_1 would also be lower.

4 Empirical Results

In this section, we empirically test the hypotheses in Section 3, using the network density measures presented in Section 2. We use several measures of liquidity: market volume, execution cost of a trade, and bid-ask spreads. To test for the relationship between these measures of liquidity and the measures of network density. we employ several models amd control for dealer, market, substitute market, and time effects.[15]

4.1 Dealer-to-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. Since client trade volume is measured at the market level, we only include measures of completeness of the interdealer (K^{D}) and the dealer-to-client (K^{C}) market networks, lagged by a period.[16]

When modeling trade volume, it is necessary to account for fundamental drivers of demand for CDS contracts. We account for demand by including variables that capture the riskiness of the underlying name, such as the CDS spread, the change in the CDS spread, and the CDS recovery rate; and variables that capture direct hedging needs such as the volume of trading in the underlying bond and CDS indices.

The model also accounts for the introduction of central clearing to U.S. CDS markets within our sample period. For each single-name reference entity, we include a clearing indicator, $\mathbb{1}_{j,t}^{\text{Clearable}}$, corresponding to whether and when that reference entity became eligible to clear at a central counterparty. We also include the share of interdealer volume, $\lambda_{j,t}^{\mathrm{D}}/\lambda_{j,t}$,, which captures the degree of difficulty in offsetting trades (Wang (2018)).

Final the model includes variables that capture time variation, $\mathbb{1}^{\mathrm{M/Y}}$, and seasonality, $\mathbb{1}^{\mathrm{M}}$, at the market level – seasonality is natural in trading volume due to the regular schedule of issuing

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

[16]We have explored models without lagging the completeness measures and found similar results – they are available upon request.

new series of CDS contracts. The model is given by:

$$\begin{aligned}\log(\lambda^{\mathrm{C}}_{j,t}) =&\beta_0 + \beta_1 \mathrm{K}^{\mathrm{D}}_{j,t-1} + \beta_2 \mathrm{K}^{\mathrm{C}}_{j,t-1} + \beta_3 \text{CDS Spread}_{j,t} + \beta_4 \Delta\text{CDS Spread}_{j,t} \\ &+ \beta_5 \text{CDS Recovery Rate}_{j,t} + \beta_6 \log(\text{Bond } \lambda_{j,t}) + \beta_7 \log(\text{Index } \lambda^{\mathrm{C}}_t) \\ &+ \beta_8 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_{82} \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} + \beta_{10-20} \mathbb{1}^{\mathrm{M}} + \beta_{21-82} \mathbb{1}^{\mathrm{M/Y}} + \epsilon.\end{aligned} \quad (6)$$

The period, t, in the regression model in Equation (6) is one week – all variables are calculated each week as many single-names CDS trade infrequently. The results, reported in Table 3, 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 are significantly positively correlated with volume.[17] The results are consistent with intuition: as the risk, measured by CDS spreads, increases, we expect hedging demand by holders of existing debt to also increase.

Table 3: Intermediation Network and Client Volume

	Dependent Variable			
	log(Client Volume)			
	(1)	(2)	(3)	(4)
Intercept	4.1000***	3.5409***	3.7766***	3.4533***
Interdealer Market Completeness		0.0082***		0.0061***
Client Market Completeness			0.0379***	0.0267***
CDS spread	1.3409***	1.2907***	1.1012***	1.1341***
ΔCDS spread	-0.2721	-0.2476	-0.1929	-0.1978
CDS Recovery Rate	0.7434***	0.5875***	0.6129***	0.5346***
log(Bond Volume)	0.1139***	0.1218***	0.1080***	0.1157***
log(Client Index CDS Volume)	0.2481***	0.2495***	0.2503***	0.2506***
CDS Clearing Eligible	-0.0005	0.0163	0.0395***	0.0402***
Interdealer Volume Share	-0.0096***	-0.0097***	-0.0097***	-0.0097***
Time Fixed Effects	Y	Y	Y	Y
Observations	36,248	36,248	36,248	36,248
Adjusted R^2	27.09%	28.29%	28.18%	28.76%

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.

We find that the eligibility of a CDS contract to be cleared s positively correlated with increasing volume, in line with Loon and Zhong (2014). This is consistent with the fact that clearing eligibility

[17]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.

is largely based on whether a particular CDS contract is part of a CDS index, and index inclusion is based on whether a CDS contract is heavily traded. The coefficient of the share of interdealer volume is negative, meaning that a higher share of interdealer trade is associated with lower client volumes.

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 6 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 27 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 Individual & Aggregate Dealer Inventory

The size of dealer inventories, both individually (x_i) and on aggregate ($\sum_i \|x_i\|$), depends on many factors including the cost that dealers face in holding inventory or trading with other market participants.[18] 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 H2 states that, for individual dealers, the completeness of their intermediation networks is positively related to their inventory. As far as market completeness, hypothesis H3 states that controlling for completeness of intermediation networks of individual dealers should be positively associated with both a dealer's inventory, as well as the aggregate, gross, 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. In addition to the network completeness measures, the explanatory variables include the client volume, $\lambda^{\mathrm{C}}_{j,t}$, the share of interdealer trade, an indicator variable capturing whether and when the CDS contract became eligible for clearing,

[18] We model dealer level inventories by the logarithm of the absolute value of individual inventories, while we measure aggregate, market, inventory by the logarithm of the sum of the absolute values of individual dealer inventories.

as well as variables that capture time variation and reference entity, $\mathbb{1}_j^{\mathrm{R}}$.

$$\log(\|x_{i,j,t}\|) = \beta_0 + \beta_1 \mathrm{K}^{\mathrm{D}}_{j,t-1} + \beta_2 \mathrm{K}^{\mathrm{C}}_{j,t-1} + \beta_3 \mathrm{k}^{\mathrm{D}}_{i,j,t-1} + \beta_4 \mathrm{k}^{\mathrm{C}}_{i,j,t-1} + \beta_5 \mathbb{1}^{\mathrm{Clearable}}_{j,t} + \beta_6 \log(\lambda^{\mathrm{C}}_{j,t}) + \beta_7 \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} + \beta_{8-89} \mathbb{1}^{\mathrm{M/Y}} + \beta_{90-386} \mathbb{1}^{\mathrm{R}}_j + \epsilon, \tag{7}$$

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

Tables 4 and 5 present the results of Equations (7) and (8). 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, at the level of individual dealers, Table 4 shows that explanatory power for individual dealer inventory increases significantly when dealer-level network measures are included in the model.

In line with hypothesis H2, the coefficients of individual dealer completeness measures are significant and positive, suggesting that better connected individual dealers hold larger inventories. The effect is significant for both the interdealer network and the client network: a 10 percent increase in the completeness of the interdealer network for an individual dealer is associated with a 13 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.

In contrast with hypothesis H3, Table 4 shows that, 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. Rather than increasing risk-bearing capacity for the entire network, this result is consistent with a more connected market being able to better spread – and net – inventories across dealers.

At the aggregate market level, the results in Table 5 demonstrate the importance of a market's intermediation network. Consistent with hypothesis H3, regarding aggregate market inventory,

Table 4: Intermediation Network and Dealer Inventory

	Dependent Variable			
	log(Dealer ‖Inventory‖)			
	(1)	(2)	(3)	(4)
Intercept	7.5027***	6.4385***	7.3278***	6.7409***
Interdealer Dealer Completeness		0.0124***		0.0129***
Client Dealer Completeness		0.0051***		0.0047***
Interdealer Market Completeness			0.0027***	-0.0052***
Client Market Completeness			0.0006	-0.0014
CDS Clearing Eligible	0.0116***	0.0251***	0.0115***	0.0263***
log(Client Volume)	0.0015	0.0032	0.0009	0.0045**
Interdealer Volume Share	0.0000	0.0000	0.0000	0.0000
Time Fixed Effects	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y
Observations	470,264	470,264	470,264	470,264
Adjusted R^2	9.14%	22.13%	9.19%	22.31%

Note: The table presents the results of Equation (7) 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.

as the completeness of the market-level interdealer and the dealer-to-client networks increases, the aggregate gross inventory level increases as well. For example, a 10 percent increase in each measure is associated with an increase in the aggregate gross inventory by 4 percent and 11 percent respectively. This finding suggests that well-connected networks have higher risk-bearing capacity, which in turn may support liquidity under periods of stress due to high client demand.

4.3 Execution Cost & Bid-Ask Spread

The network of trading relationships between dealers and clients has the potential to influence, and reflects, the cost of executing a trade, not just for individual dealers, but for the entire market. Hypothesis H4 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 H5 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.

We consider two measures of trading cost for a transaction: the execution cost and the bid-ask

Table 5: Intermediation Network and Market Inventory

	Dependent Variable			
	log(Σ Individual Dealer ‖Inventory‖)			
	(1)	(2)	(3)	(4)
Intercept	8.5227***	8.2679***	8.3913***	8.2076***
Interdealer Market Completeness		0.0042***		0.0035***
Client Market Completeness			0.0172***	0.0106***
CDS Clearing Eligible	0.0904***	0.0916***	0.0921***	0.0924***
log(Client Volume)	0.0158***	0.0146***	0.0149***	0.0143***
Interdealer Volume Share	0.0002***	0.0002***	0.0002***	0.0002***
Time Fixed Effects	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y
Observations	36,508	36,508	36,508	36,508
Adjusted R^2	81.54%	82.05%	81.86%	82.15%

Note: The table presents the results of Equation (8) 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.

spread. We define the execution cost, μ, as

$$\mu_{i,j,t} = \frac{\text{CDS Transaction Spread}_{i,j,t} - \text{CDS Spread}_{j,t}}{\text{CDS Spread}_{j,t}}(2 \times \mathbb{1}^{\text{buyer}} - 1). \tag{9}$$

While the bid-ask spread captures the cost of transacting irrespective of who the buyer and who the seller is, 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; one model for the case when the dealer trades with a client – execution cost $\mu^C_{i,j}$ – and another for the case when the dealer trades with another dealer – execution cost $\mu^D_{i,j}$. In addition to the network completeness measures, the explanatory variables include the number of dealers with positions in reference entity $j, |\mathcal{D}_j|$, and, in an effort to capture potential inventory costs, several variables involving dealer inventory. These variables are the level of the inventory of individual dealer i for reference entity j, $\log(\|x_{i,j}\|)$, the aggregate net market inventory $\log(\|X_j\|)$, the aggregate gross market inventory $\log(\sum_i \|x_{i,j}\|)$, as well as the aggregate, gross, inventory separated in long and short positions.[19]

[19] The separation in long and short positions is meant to capture potential differences in client motivations between buying and selling CDS contracts.

The remaining variables control for the dealer share of total volume, time variation, reference entity fixed effects, and whether the CDS contracts on a reference entity are eligible for clearing.

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

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

Table 6 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 inventory of the transacting dealer, suggesting that dealers with large inventories have difficulty offloading risk when trading with clients. We do not find evidence that execution cost in transactions with clients depends on market inventory, either net or gross. We also do not find support for hypotheses H4 and H5 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 7 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. On the other hand, the execution cost depends on whether contracts on a reference entity are eligible to clear: contracts that are eligible to clear are more expensive to trade with other dealers by 13 basis points, indicating that clearing may be costly. We find some support for hypothesis H4, as we find that a 10 percent increase in a dealer's client network completeness decreases her interdealer execution trade by 42 basis points.

However, we do not find support for hypothesis H5 after controlling for a dealer's client network. Instead of an association of lower costs with higher levels of market completeness for the dealer-client market network, we find that as completeness increases, interdealer execution costs increase as well. A potential explanation lies in the interplay between interdealer trade costs and a dealer's need to offset client trades. Similar to the shown in Table 4 for hypothesis H3, it is possible that, as a dealer's dealer-to-client network becomes denser, she has less need to offset positions through

Table 6: Intermediation Network and Dealer-to-Client Execution Cost

	Dependent Variable							
	Execution Cost							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	11.9999	12.3214*	12.5711*	12.6053*	6.6116	7.1010	7.8261	7.8430
Interdealer Dealer Completeness		-0.0121		-0.0126		-0.0132		-0.0124
Client Dealer Completeness		0.0147		0.0156		0.0150		0.0159
Interdealer Market Completeness			-0.0061	0.0027			-0.0122	-0.0037
Client Market Completeness			-0.0209	-0.0485			-0.0276	-0.0556
log(Dealer ‖Inventory‖)	0.4017***	0.3893***	0.4007***	0.3883**	0.3894***	0.3781**	0.3876**	0.3742**
log(‖Net All Dealer Inventory‖)	-0.1585	-0.1497	-0.1565	-0.1444	-0.2898	-0.2787	-0.2854	-0.2745
log(All Dealer ‖Inventory‖)	-1.7215*	-1.6260	-1.6213	-1.5971				
log(All Long Dealer Inventory)					-0.6522	-0.6242	-0.6131	-0.6118
log(All Short Dealer ‖Inventory‖)					-0.3623	-0.2978	-0.2388	-0.2115
CDS Clearing Eligible	0.3545	0.3123	0.3473	0.3057	0.3110	0.2669	0.2984	0.2560
Number of Market Dealers	-0.0608	-0.0879	-0.1013	0.0987	-0.0631	-0.0928	-0.1368	-0.1344
Interdealer Volume Share	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations	284,008	284,008	284,008	284,008	284,008	284,008	284,008	284,008
Adjusted R^2	1.87%	1.87%	1.87%	1.88%	1.87%	1.87%	1.87%	1.87%

Note: The table presents the results of Equation (10) 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 between a client and a dealer.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

the interdealer network and may only do so when the execution costs are low. However, if the dealer-client market completeness increases because all dealers have higher dealer-to-client network completeness, the cost to trade with another dealer increases since both the individual dealer's network is no longer as advantageous and the need for interdealer transactions declines, causing execution costs to grow.

Our last measure of the cost of trading a CDS contract is 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.[20] We define the bid-ask spread (γ) to be:

$$\gamma_{i,j,t} = \left| \frac{\text{CDS Transaction Spread}_{i,j,t} - \text{CDS Spread}_{j,t}}{\text{CDS Spread}_{j,t}} \right|. \tag{12}$$

We construct two models of the bid-ask spread, one for transactions between dealers and clients, $\gamma^{C}_{i,j}$, and the other for transactions between dealers, $\gamma^{D}_{i,j}$. The explanatory variables are the same as in the models for dealer execution costs.

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

$$\begin{aligned} \gamma^{\mathrm{D}}_{i,j,t} =& \beta_0 + \beta_1 \mathrm{K}^{\mathrm{D}}_{j,t-1} + \beta_2 \mathrm{K}^{\mathrm{C}}_{j,t-1} + \beta_3 \mathrm{k}^{\mathrm{D}}_{i,j,t-1} + \beta_4 \mathrm{k}^{\mathrm{C}}_{i,j,t-1} + \beta_5 \log(\|x_{i,j,t}\|) + \beta_6 \log(\|\mathrm{X}_{j,t}\|) \\ &+ \beta_7 \log(\textstyle\sum_i \|x_{i,j,t}\|) + \beta_8 \mathbb{1}^{\mathrm{Clearable}}_{j,t} + \beta_9 |\mathcal{D}_{j,t}| + \beta_{10} \lambda^{\mathrm{D}}_{j,t}/\lambda_{j,t} + \beta_{11-92} \mathbb{1}^{\mathrm{M/Y}} + \beta_{93-389} \mathbb{1}^{\mathrm{R}}_{j} + \epsilon. \end{aligned} \tag{14}$$

Table 8 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 increases with the total, aggregate, gross market inventory, although not with the net market inventory. This result suggests that bid-ask spreads between

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

Table 7: Intermediation Network and Interdealer Execution Cost

	Dependent Variable							
	Execution Cost							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	0.1714	0.6737	0.1877	0.5627	0.0991	0.5305	0.1262	0.4023
Interdealer Dealer Completeness		0.0078		0.0092		0.0078		0.0092
Client Dealer Completeness		-0.0409***		-0.0422***		-0.0408***		-0.0422***
Interdealer Market Completeness			-0.0006	-0.0078			-0.0007	-0.0079
Client Market Completeness			0.0036	0.0746***			0.0034	0.0745***
log(Dealer ‖Inventory‖)	0.0043	0.0774	0.0042	0.0767	0.0042	0.0774	0.0042	0.0766
log(‖Net All Dealer Inventory‖)	-0.0035	-0.0063	-0.0038	-0.0136	-0.0071	-0.0154	-0.0072	-0.0179
log(All Dealer ‖Inventory‖)	-0.0625	-0.1748	-0.0605	-0.1959**				
log(All Long Dealer Inventory)					-0.0318	-0.0888*	-0.0299	-0.0652
log(All Short Dealer ‖Inventory‖)					-0.0213	-0.0673	0.0034	-0.1117*
CDS Clearing Eligible	0.0537***	0.1345***	0.0531***	0.1336***	0.0533***	0.1338***	0.0527***	0.1327***
Number of Market Dealers	0.0118	0.0285	0.0104	0.0276	0.0119	0.0288	0.0100	0.0269
Interdealer Volume Share	0.0000	-0.0003	0.0000	-0.0002	0.0000	-0.0003	0.0000	-0.0002
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154
Adjusted R^2	0.01%	0.10%	0.01%	0.10%	0.01%	0.10%	0.01%	0.10%

Note: The table presents the results of Equation (11) 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 between dealers.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

dealers and clients increase with the volume of trading, even when trading is balanced, potentially due to costs associated with holding more inventory on the balance sheet of the dealers. In line with hypothesis H4, the network measures indicate that the dealer-to-client bid-ask spreads are smaller when 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 more central dealers 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 9 presents the results for the magnitude of the bid-ask spread for interdealer 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 95-103 basis points, a further indication that clearing may increase costs for dealers. Among the network measures, we do not find support for hypothesis H4 as the completeness of the intermediation network of individual dealers is not significant. However, there is support for hypothesis H5, as the market completeness 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 the bid-ask spread for CDS contracts on that reference entity. The results highlight that well-connected networks allow for lower trading costs and are consistent with more complete networks being associated with larger risk-sharing capacity by intermediaries.

Table 8: Intermediation Network and Dealer-to-Client Bid-Ask Spreads

	Dependent Variable							
	Bid-Ask Spread							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	8.1679	12.5522**	12.6502*	14.4924**	6.0783	10.8390*	11.4561*	13.2079*
Interdealer Dealer Completeness		-0.0551***		-0.0468***		-0.0547***		-0.0462***
Client Dealer Completeness		0.0000		-0.0008		0.0001		-0.0008
Interdealer Market Completeness			-0.0695***	-0.0381			-0.0694***	-0.0385
Client Market Completeness			-0.0199	-0.0227			-0.0108	-0.0138
log(Dealer ‖Inventory‖)	-0.5635***	-0.4793***	-0.5743***	-0.4963***	-0.5685***	-0.4849***	-0.5785***	-0.5014***
log(‖Net All Dealer Inventory‖)	-0.3215*	-0.3028*	-0.3195*	-0.3036*	-0.1162	–0.0976	-0.1001	-0.0915
log(All Dealer ‖Inventory‖)	1.2448*	1.5369***	2.0847***	2.1290***				
log(All Long Dealer Inventory)					1.5825**	1.6221***	1.8043***	1.7378***
log(All Short Dealer ‖Inventory‖)					-0.1898	0.0175	0.3523	0.2936
CDS Clearing Eligible	-0.1347	-0.1967	-0.1893	-0.2171	-0.1256	-0.1873	-0.1778	-0.2059
Number of Market Dealers	0.0264	-0.1215	-0.3314***	-0.3014**	0.0135	-0.1320	-0.3368***	-0.3077**
Interdealer Volume Share	-0.0049	-0.0044	-0.0044	-0.0042	-0.0049	-0.0044	-0.0044	-0.0042
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations	284,008	284,008	284,008	284,008	284,008	284,008	284,008	284,008
Adjusted R^2	5.00%	5.06%	5.03%	5.07%	5.02%	5.08%	5.04%	5.09%

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 bid-ask spread of a transaction between a client and a dealer.
Source: Authors' calculations, which use data provided to the OFR by the Depository Trust & Clearing Corporation.

Table 9: Intermediation Network and Interdealer Bid-Ask Spreads

	Dependent Variable							
	Bid-Ask Spread							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Intercept	15.0386***	16.1376***	21.1550***	21.2713***	14.4430***	15.6112***	21.4461***	21.5435***
Interdealer Dealer Completeness		-0.0135		-0.0029		-0.0132		-0.0028
Client Dealer Completeness		-0.0025		-0.0037		-0.0024		-0.0038
Interdealer Market Completeness			-0.0694***	-0.0673***			-0.0680***	-0.0660***
Client Market Completeness			-0.0941**	-0.0884*			-0.0860	-0.0802
log(Dealer ‖Inventory‖)	-0.0424	-0.0037	-0.0496	-0.0339	-0.0464	-0.0083	-0.0517	-0.0362
log(‖Net All Dealer Inventory‖)	-0.2575**	-0.2565**	-0.2442**	-0.2449**	-0.1298	-0.1302	-0.1184	-0.1196
log(All Dealer ‖Inventory‖)	0.3847	0.4419	1.2815***	1.2574***				
log(All Long Dealer Inventory)					0.8887***	0.8884***	1.0362***	1.0279***
log(All Short Dealer ‖Inventory‖)					-0.5034	-0.4556	0.1152	0.1017
CDS Clearing Eligible	1.0337***	1.0180***	0.9396***	0.9445***	1.0325***	1.0175***	0.9453***	0.9504***
Number of Market Dealers	-0.1540***	-0.1903***	-0.5636***	-0.5582***	-0.1623***	-0.1976***	-0.5587***	-0.5535***
Interdealer Volume Share	0.0064***	0.0068***	0.0071***	0.0071***	0.0062***	0.0063***	0.0070***	0.0070***
Time Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y	Y	Y	Y	Y
Observations	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154	1,011,154
Adjusted R^2	9.37%	9.38%	9.44%	9.44%	9.38%	9.39%	9.44%	9.45%

Note: The table presents the results of the Equation (14) 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 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 affects 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, dealer inventory management, and the cost of trade, measured by both execution cost and bid-ask spreads.

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 from 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 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 challenge theoretical predictions that more complete markets always lower execution costs and narrow bid-ask spreads. We find 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 suggests a relationship between interdealer trade and the demand for 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 relationship between network changes – and specifically network completeness – and 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.

References

Adrian, T., Boyarchenko, N., and Shachar, O. (2017). Dealer balance sheets and bond liquidity provision. *Journal of Monetary Economics*, 89:92–109.

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

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

Bao, J., O'Hara, M., and Zhou, A. (2018). The Volcker rule and market-making in times of stress. *Journal of Financial Economics*, 130:95–113.

Bessembinder, H., Jacobsen, S. E., Maxwell, W. F., and Venkataraman, K. (2018). Capital commitment and illiquidity in corporate bonds. *The Journal of Finance*, 73:1615–1661.

Brewer, E. and Jackson, W. E. (2000). Requiem for a market maker: the case of drexel burnham lambert and junk bonds. *Journal of Financial Services Research*, 17(3):209–235.

Carapella, F. and Monnet, C. (2020). Dealers' insurance, market structure, and liquidity. BIS Working Paper.

Chang, B. and Zhang, S. (2019). Endogenous market making and network formation. Working Paper.

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

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

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

Du, W., Gadgil, S., Gordy, M. B., and Vega, C. (2016). Counterparty risk and counterparty choice in the credit default swap market. Finance and Economics Discussion Series 2016-087, Board of Governors of the Federal Reserve System.

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

D'Errico, M., Battiston, S., Peltonen, T., and Scheicher, M. (2018). How does risk flow in the credit default swap market? *Journal of Financial Stability*, 35:53–74.

Eisfeldt, A., Herskovic, B., Rajan, S., and Siriwardane, E. (2018). OTC intermediaries. Office of Financial Research Working Paper 18-05.

Elliott, M. (2015). Inefficiencies in networked markets. *American Economic Journal: Microeconomics*, 7(4):43–82.

Garman, M. B. (1976). Market microstructure. *Journal of Financial Economics*, 3(3):257–275.

Gofman, M. (2011). A network-based analysis of over-the-counter markets. In *AFA 2012 Chicago Meetings Paper*.

Gofman, M. (2017). Efficiency and stability of a financial architecture with too-interconnected-to-fail institutions. *Journal of Financial Economics*, 124(1):113–146.

Hansch, O., Naik, N. Y., and Viswanathan, S. (1998). Do inventories matter in dealership markets? Evidence from the London stock exchange. *The Journal of Finance*, 53:1623–1656.

Ho, T. S. Y. and Stoll, H. R. (1983). The dynamics of dealer markets under competition. *The Journal of Finance*, 38:1053–1074.

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

Hugonnier, J., Lester, B., and Weill, P.-O. (2020). Frictional intermediation in over-the-counter markets. *The Review of Economic Studies*, 87(3):1432–1469.

Iercosan, D. and Jiron, A. A. (2017). The value of trading relationships and networks in the CDS market. Working paper.

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

Loon, Y. C. and Zhong, Z. K. (2014). The impact of central clearing on counterparty risk, liquidity, and trading: Evidence from the credit default swap market. *Journal of Financial Economics*, 112(1):91–115.

Neklyudov, A. (2019). Bid-ask spreads and the over-the-counter interdealer markets: Core and peripheral dealers. *Review of Economic Dynamics*, 33:57–84.

Oehmke, M. and Zawadowski, A. (2015). Synthetic or real? the equilibrium effects of credit default swaps on bond markets. *The Review of Financial Studies*, 28(12):3303–3337.

Oehmke, M. and Zawadowski, A. (2017). The anatomy of the cds market. *The Review of Financial Studies*, 30(1):80–119.

Peltonen, T. A., Scheicher, M., and Vuillemey, G. (2014). The network structure of the CDS market and its determinants. *Journal of Financial Stability*, 13:118–133.

Reiss, P. C. and Werner, I. M. (1998). Does risk sharing motivate interdealer trading? *The Journal of Finance*, 53(5):1657–1703.

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

Shachar, O. (2012). Exposing the exposed: Intermediation capacity in the credit default swap market. Working Paper.

Siriwardane, E. N. (2019). Limited investment capital and credit spreads. *The Journal of Finance*, 74(5):2303–2347.

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

Viswanathan, S. and Wang, J. J. (2004). Inter-dealer trading in financial markets. *The Journal of Business*, 77(4):987–1040.

Wang, C. (2018). Core-periphery trading networks. Wharton Working Paper.

Wang, X. and Zhong, Z. K. (2020). Dealer inventory, pricing, and liquidity in the OTC derivatives markets: Evidence from index CDSs. *Journal of Financial Markets*. forthcoming.

Yang, M. and Zeng, Y. (2019). The coordination of intermediation. University of Washington Working Paper.

A Regression Variable Definitions

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_t^{C}	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
$\mathbb{1}_{j,t}^{\text{Clearable}}$	Eligible to clear indicator variable for reference entity j at time period t capturing clearing fixed effects
$\mathbb{1}^{\text{M}}$	Month indicator variables capturing seasonality fixed effects
$\mathbb{1}^{\text{M/Y}}$	Year-month indicator variables capturing time fixed effects
$\lambda_{j,t}^{\text{C}}$	Client CDS volume for reference entity j at time period t
$\lambda_{i,j}^{\text{D}}$	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
$\lambda_{j,t}^{\text{D}}/\lambda j,t$	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
$\text{X}_{j,t}$	Absolute value of net aggregate inventory for reference entity j during time period t
$\text{K}_{j,t}^{\text{D}}$	Market's network completeness of interdealer network of reference entity j at time period t
$\text{K}_{j,t}^{\text{C}}$	Market's network completeness of dealer-to-client network of reference entity j at time period t
$\text{k}_{j,t}^{\text{D}}$	Dealer's network completeness with other dealers of reference entity j at time period t
$\text{k}_{j,t}^{\text{C}}$	Dealer's network completeness with clients of reference entity j at time period t
$\mu_{i,j,t}^{\text{C}}$	Execution cost relative to Markit spread for dealer-to-client transactions for dealer i, reference entity j during time period t
$\mu_{i,j,t}^{\text{D}}$	Execution cost relative to Markit spread for interdealer transactions for dealer i, reference entity j at time period t
$\gamma_{i,j,t}^{\text{C}}$	Bid-ask spread relative to Markit spread for dealer-to-client transactions for dealer i, reference entity j at time period t
$\gamma_{i,j,t}^{\text{D}}$	Bid-ask spread relative to Markit spread for interdealer transactions for dealer i, reference entity j at time period t
log(Dealer $\|\text{Inventory}\|_{i,j,t}$)	Logarithm of the absolute value of the inventory of individual dealer i for reference entity j at time period t
log($\|\text{Net All Dealer Inventory}\|_{j,t}$)	Logarithm of the absolute value of aggregate, net, inventory for reference entity j at time period t
log(All Dealer $\|\text{Inventory}\|_{j,t}$)	Logarithm of the sum of the absolute values of dealer inventories for reference entity j at time period t
log(All Dealer Long $\text{Inventory}_{j,t}$)	Logarithm of the sum of the inventories of dealers that are long CDS contracts for reference entity j at time period t
log(All Dealer Short $\|\text{Inventory}\|_{j,t}$)	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.

B Additional Hypotheses

Our focus in the paper is on liquidity, both at the level of individual dealers and at the aggregate, market, level. Beyond the liquidity measures we consider in the body of the paper, we have also considered two additional, related, measures: the fraction of interdealer trade, and the number of dealers intermediating in a single-name CDS market. Based on the literature, we formulate and test hypotheses for each of these variables below.

B.1 Interdealer Volume Share

HA.1: *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.*

HA.1 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.

In equilibrium, Wang (2018) 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}. We test whether this prediction holds empirically using the following model:

$$\frac{\lambda_{j,t}^{\mathrm{D}}}{\lambda_{j,t}} = \beta_0 + \beta_1(\log(\lambda_{j,t}^{\mathrm{C}}) \wedge \log(\lambda_{j,t})) + \beta_2 \mathbb{1}_{j,t}^{\mathrm{Clearable}} + \beta_{3-84}\mathbb{1}^{\mathrm{M/Y}} + \beta_{85-381}\mathbb{1}_j^{\mathrm{R}} + \epsilon. \tag{B.15}$$

The results, presented in Table B.1, are in line with Hypothesis HA.1; i.e., they confirm a negative and significant relationship between client volume and the share of interdealer volume. The results also 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.

B.2 Number of Dealers

HA.2: *The completeness of a market's intermediation network is negatively related to the number of dealers in a market.*

The intuition behind HA.2 is that an increase in the completeness of the intermediation network lowers

Table B.1: 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 (B.15) 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.

the search costs for dealers and reduces individual dealer inventories. The hypothesis is in line with the theoretical proposition in Carapella and Monnet (2020), where the number of dealers decreases as their search options increase; i.e., the market concentration increases. 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.

We investigate the relationship between the number of dealers and network measures of completeness with the model

$$\begin{aligned}|\mathcal{D}_{j,t}| =& \beta_0 + \beta_1 \mathbb{1}^{\text{Clearable}}_{j,t} + \beta_2 \text{K}^{\text{D}}_{j,t} + \beta_3 \text{K}^{\text{C}}_{j,t} + \beta_4 \log(\lambda^{\text{C}}_{j,t}) \\ &+ \beta_5 \lambda^{\text{D}}_{j,t}/\lambda_{j,t} + \beta_{6-87} \mathbb{1}^{\text{M/Y}} + \beta_{88-384} \mathbb{1}^{\text{R}}_j + \epsilon.\end{aligned} \tag{B.16}$$

The results presented in Table B.2 show that the relationship between client volume and the number of dealers, as well as the relationship between the interdealer volume share and the number of dealers are 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, while doubling client volume increases the number of dealers by 0.02. On the other hand, consistent with hypothesis HA.2, 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, while a 10 percent increase in dealer-to-client market completeness is associated with a decrease in the number of dealers by 0.8. 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.

Table B.2: Intermediation Network and Number of Market Dealers

	Dependent Variable			
	Number of Dealers			
	(1)	(2)	(3)	(4)
Intercept	21.4779***	27.3238***	24.0301***	27.7914***
Interdealer Market Completeness		-0.0971***		-0.0913***
Client Market Completeness			-0.2552***	-0.0816***
CDS Clearing Eligible	0.1511***	0.1244***	0.1679***	0.1181***
log(Client Volume)	0.0044	0.0310***	0.0176	0.0337***
Interdealer Volume Share	0.0004	0.0013***	0.0005*	0.0012***
Time Fixed Effects	Y	Y	Y	Y
Reference Entity Fixed Effects	Y	Y	Y	Y
Observations	36,511	36,511	36,511	36,511
Adjusted R^2	86.78%	92.96%	88.37%	93.10%

Note: The table presents the results of Equation (B.16) 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.