The Cost of Clearing Fragmentation*

Evangelos Benos[1], Wenqian Huang[2], Albert J. Menkveld[3], and Michalis Vasios

[1]University of Nottingham
[2]Bank for International Settlements
[3]Vrije Universiteit Amsterdam

October 24, 2022

Abstract

Fragmenting clearing across multiple central counterparties (CCPs) is costly because global dealers cannot net positions across CCPs. They have to collateralize both the short position in one CCP *and* an offsetting long position in another CCP. This, coupled with a structural net order imbalance across CCPs, can cause prices to persistently differ across them ("the CCP basis"). Tests based on unique CCP data for interest-rate derivatives (IRDs), yield broad empirical support for this intuition and suggest that the clearing friction costs sellers clearing in LCH, the largest European CCP for IRDs, \$80 million *daily*.

JEL Classification: G10, G12, G14
Keywords: central clearing, CCP basis, collateral, fragmentation

*Evangelos Benos: Evangelos.Benos@nottingham.ac.uk. Wenqian Huang: Wenqian.Huang@bis.org. Albert J. Menkveld: albertjmenkveld@gmail.com. Michalis Vasios: michalis.v@gmail.com. We would like to thank Tobias Berg, Stijn Claessens, Darrell Duffie, Edward Gaffney, Elmar Nijkamp, Eric Schaaning, Corinna Schempp, Mila Getmansky Sherman, Nikola Tarashev, Guillaume Vuillemey, Ansgar Walther, Chaojun Wang, Shihao Yu, and seminar participants at the Bank of England, the Bank for International Settlements, the US Commodity Futures Trading Commission, the University of East Anglia, the University of Cyprus, the University of Nottingham, the University of Piraeus, the World Federation of Exchanges, as well as participants at the 2019 workshop on "The Economics of Central Clearing" at the Paris School of Economics, the 2019 LSE-Imperial-BOE-CEPR conference on Non-bank Financial Institutions and Financial Stability, the 5th IWH-FIN-FIRE workshop on "Challenges to Financial Stability," the 2019 Conference on Research on Economic Theory and Econometrics (CRETE), the 2019 workshop of the Financial Intermediation Network of European Studies, the 2020 European Finance Association conference, the 2020 Annual Meeting of the Central Bank Research Association, the Microstructure Exchange, the 2021 Plato Market Innovator Conference and the 5th SAFE Market Microstructure Conference for helpful comments and suggestions. We would also like to thank ClarusFT for providing us with data on switch trades. Albert Menkveld gratefully acknowledges the support of an NWO Vici grant. Michalis Vasios worked on this project while at the Bank of England. The views expressed in this paper are those of the authors, and not those of the Bank of England or the Bank for International Settlements or the European Securities and Markets Authority.

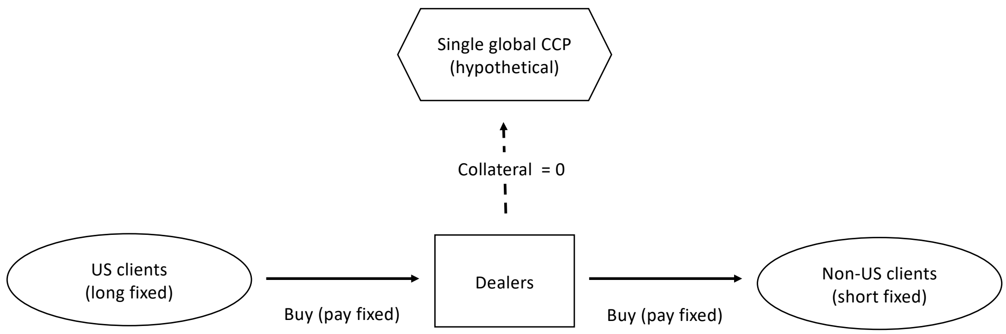
1 Introduction

To address counterparty risk, the G20 mandated central clearing of standardized derivatives after the 2007-2008 financial crisis. Any trade in, for example, a USD fixed-to-floating interest-rate swap needs a central counterparty (CCP) to insure counterparty risk. Should one side of the trade fail on its commitments, the CCP steps in and effectively becomes the new counterparty to honor the outstanding commitments. To protect itself, the CCP requires participants to post collateral (i.e., initial margin) commensurate to the size of their commitments.[1]

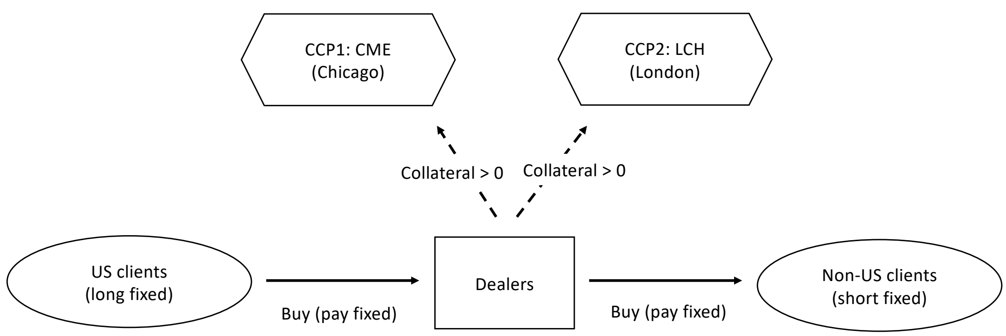
International securities markets (including derivatives) allow local economic exposures to be shared globally, thus efficiently transferring risk. End-user investors, therefore, trade across jurisdictions. Some investors, however, might be constrained, either by regulation or by cost, to trade (and clear their trades) within their own jurisdiction. Global dealers step in to trade with these investors locally, while aiming to keep their global net position zero. Even if the hedge is perfect (i.e., dealers keep their global net position zero), fragmented clearing implies that the dealers have to post collateral with the local CCPs for non-zero local positions. Dealers recoup these costs by trading with their clients at different price levels in the various local markets. The market where sellers dominate gets a lower price than the one where buyers do. This price differential is referred to as the "CCP basis."

Figure 1 illustrates the cost of fragmented clearing for the case of USD interest-rate swaps. US local banks selling fixed-rate mortgages, for example, hedge these exposures by "buying" (i.e., paying fixed) from global dealers. These dealers, in turn, hedge these positions by trading with international investors in London. If, as in panel (a), there were a single global CCP, the dealers would be able to net these positions and therefore would not have to post initial margin. Panel (b) shows that, in reality, the trade between the US banks and the dealers will be cleared in the Chicago Mercantile Exchange (CME), while that between the dealers and the international investors will be cleared in LCH in London. Thus, the dealers have to post margin at both CME and LCH. This is

[1] The interest-rate derivatives market is, by far, the largest derivatives market in terms of outstanding notional. At the end of 2021, the notional stood at $475 trillion with 78% of it being centrally cleared. For detailed information on aggregate outstanding notional amounts in various Over-The-Counter (OTC) derivatives, see https://stats.bis.org/statx/srs/table/d5.1?p=20152&c=.



(a) Single CCP



(b) Multiple CCPs

Figure 1: Single vs. multiple CCPs
This figure illustrates how imbalanced order flow across two pools of investors served by different CCPs can impose non-zero collateral costs on dealers. The figure depicts the case of US clients who hedge their long positions in USD fixed rates (due to, e.g., banks selling fixed-rate mortgages) with, ultimately, non-US clients. Panel (a) illustrates the hypothetical case of a single global CCP. Panel (b) illustrates the real-world case of global dealers clearing with US clients at CME in Chicago and with non-US clients at LCH in London.

costly to dealers not only because margin needs to be funded by tapping capital markets but also because of debt overhang (Andersen, Duffie and Song, 2019): To the extent that margin is funded by liabilities (debt or equity), that have lower seniority than existing debt, it renders the latter safer and therefore increases its market value at the expense of existing shareholders.

Dealers recoup this cost by charging the net buyers in the US a higher price than the net sellers outside of the US. The resulting CME-LCH basis (CME minus LCH) is one to four basis points in our 2014-2016 sample for USD interest rate swaps.[2]. The basis may seem small but multiplied by daily volume this costs LCH sellers about $80 million, *per day*.[3]

Clearing fragmentation is not unique to USD interest-rate swaps. Other examples include (i) EUR interest-rate swaps being cleared by LCH and by Eurex in Frankfurt, and (ii) JPY swaps being cleared by LCH and by the Japan Securities Clearing Corporation (JSCC). Additionally, there is scope for clearing to further fragment in the near future as a result of "location policies" that effectively require systemically important CCPs to migrate part of their business to the home jurisdiction of some of its clearing members.[4]

Although these instances of clearing fragmentation and their associated bases have been known to market participants and have been attributed to dealer collateral costs, our paper is the first to empirically test this explanation.[5] Our paper also states (and empirically tests) new hypotheses about CCP bases, namely that their magnitude also depends on the trading activity of sophisticated (i.e. location-flexible) investors, as well as on dealers' debt overhang and the associated transfer

[2]The CME-LCH basis being positive could be explained, as stated earlier, by hedging needs of US banks selling fixed-rate mortgages. Such hedging is particularly important in a cycle of rate hikes. In the summer of 2019, however, the Fed started a rate-cut cycle. The basis turned negative at this time. This could be explained by US banks discontinuing the hedge (to benefit from the expected rate cuts), coupled with a desire of US investors to enter short positions (i.e., receiving fixed and paying floating rates)

[3]See Section 3.2 for more details on how this cost is calculated.

[4]For example, the European Market Infrastructure Regulation (EMIR) prohibits a third-country CCP to provide services to clearing members in the European Union (EU) unless recognised by the European Securities and Markets Authority (ESMA), the EU's market regulator. This includes systemically important CCPs (Tier 2 CCPs) that need to fulfil a number of additional conditions for them to be recognised and permitted to provide clearing services in the EU. ESMA is proposing "appropriate incentives for reducing the size of EU exposures to Tier 2 CCPs". For additional information on the treatment of CCPs under EMIR see here: https://www.esma.europa.eu/press-news/esma-news/esma-publishes-results-its-assessment-systemically-important-uk-central.

[5]See for example the entry on the CCP basis in the risk glossary of Risk.net here: https://www.risk.net/definition/ccp-basis. For a more detailed exposition, we refer to Amir Khwaja's (ClarusFT) discussion of the likely reasons for CCP bases and the need to empirically test them: https://www.clarusft.com/cme-lch-basis-spreads/.

of credit risk. We test our hypotheses using a 2014-2016 sample of proprietary collateral and transactions data on dollar-denominated interest-rate derivatives.

Before turning to the results in more detail, let us position our study in the current literature.[6] Duffie and Zhu (2011) made the point that from a collateral-saving perspective, it is best to organize all clearing in a single CCP.[7] Garleanu and Pedersen (2011) show how collateral cost enters equilibrium asset prices. Combining these two insights suggests that fragmented clearing can cause prices to deviate from the "law of one price".

The economic intuition behind our hypotheses is similar to what classic inventory models predict for how inventories relate to prices. If risk-averse dealers are long relative to their target positions, they optimally skew their prices downwards so that they slide below fundamental value, causing price pressures (Amihud and Mendelson, 1980; Ho and Stoll, 1981; Hendershott and Menkveld, 2014). These price pressures help reduce inventory given that low asks make it cheap to buy from the dealer and low bids make it unattractive to sell to the dealer.

The classic inventory friction however does not deliver a basis across markets. Although it can explain why prices in markets may slide above or below fundamental value, it cannot explain why prices *differ* across markets. However, if one adds the friction that a non-zero inventory carries collateral cost, as CCPs require initial margin that scales with inventory, then one *can* generate a non-zero basis. More precisely, if clearing is fragmented across markets, then each CCP requires collateral proportional to the inventory the dealer holds in the CCP's local market only. In that case, a non-zero CCP basis can arise as posting collateral locally is costly to the dealer.

A simple example will clarify this insight that underpins our analysis. Consider a dealer trading a single security in two markets: X and Y. Each market has their trades cleared by a local CCP. Each CCP requires the dealer to post margin, that scales with the dealer's inventory, in the *local market only.* Now consider the case where the dealer is long one unit in X, and long one unit in Y. In this case there is no basis in equilibrium. The equilibrium price in both markets exhibits negative price pressure, which means that it is below the fundamental value. Since the size of this

[6] Menkveld and Vuillemey (2021) survey the burgeoning literature on central clearing.

[7] Garratt and Zimmerman (2020) extend this work in more realistic networks of exposures. The extent of netting opportunities to save on collateral has also been an important criterion for policy makers when assessing various clearing arrangements (Singh, 2009, 2013; Sidanius and Zikes, 2012).

price pressure is equal across markets, there is no price differential across markets and the basis therefore is zero. If, however, the dealer is *short* one unit in Y, then equilibrium prices would imply a non-zero basis. The dealer desires to sell in X – to reduce margin – resulting in a negative price pressure in X. In Y, however, he desires to buy – again to reduce margin – resulting in a positive price pressure in Y.[8]

Based on this line of argument, we state the following hypotheses:

1. The CCP basis increases in the amount of collateral pledged by dealers.

2. The CCP basis declines in the proportion of investors who can access markets outside of their jurisdiction. The reason for that is that there is less local-demand imbalance across markets and therefore less friction, resulting in a lower price differential.

3. The CCP basis grows in dealer credit risk because of debt overhang and the associated transfer of credit risk from senior creditors to shareholders.

4. The relationships hypothesized thus far are stronger for longer-maturity contracts as these are riskier and therefore require more collateral.

5. Dynamically, if in response to the CCP basis, the high-price market attracts more investor sell flow and the low-price market more investor buy flow, then the CCP basis will subsequently shrink.

We test these hypotheses using proprietary data from LCH's SwapClear service, from January 2014 to June 2016. The data include the amounts of own collateral pledged by the participating dealers as well as transactions in all products that are part of the SwapClear netting set, namely interest-rate swaps (IRSs), forward rate agreements (FRAs) and overnight index swaps (OISs). An important feature of our data is that it identifies counterparties. This allows us (i) to isolate dealer and client activity and (ii) to identify non-dealer banks who can flexibly clear their trades in the CCP (i.e. location) of their choosing.

[8]It is worth mentioning here that the CCP basis is not directly related to whether dealers net their derivatives positions or not on their balance sheets for regulatory reporting purposes. This is because regardless of whether reporting is done on a gross or net basis, dealers operating across clearing houses still need to pledge collateral with each clearing house, which is costly.

We find broad support in the data for these hypotheses. Both the collateral pledged by dealers and their credit spread correlate positively with the size of the CME-LCH basis. The proportion of volume in SwapClear products executed by non-dealer banks, a proxy for investors who can clear flexibly, correlates negatively with the size of the basis. These effects are stronger for longer maturity contracts. Finally, impulse response functions, based on VARX model estimates, lend empirical support for the final hypothesis on model dynamics. A *positive* net volume shock for trades that are cleared at LCH where contracts trade at lower prices, is followed by a decline in the CCP basis (i.e., the basis shrinks).

Position in the broader literature. Our findings on how fragmented clearing can lead to economically meaningful price distortions add to the larger literature on intermediary-based asset pricing. It is well documented that dealer inventory cost affects prices for equities (see e.g. Naik and Yadav, 2003; Hendershott and Menkveld, 2014), US Treasuries (see e.g. Fleming and Rosenberg, 2008) and corporate bonds (see e.g. Randall, 2015; Schultz, 2017; Friewald and Nagler, 2019).

More recent studies focus on how regulation affects dealer balance sheets and, in turn, their ability to make markets. Andersen et al. (2019) articulate how, in the presence of debt overhang, the posting of collateral results in funding value adjustments that dealers ultimately pass on to their clients. Debt overhang is a result of increased credit risk among dealers, in the post-crisis period, which in turn is caused by new bail-in rules on bank resolution and a resulting perception that institutions are no longer "too-big-to-fail." Du, Tepper and Verdelhan (2018), Fleckenstein and Longstaff (2020), and Cenedese, Corte and Wang (2021) show that constraints on bank balance sheets induced by capital regulation play a role in sustaining deviations from the Covered Interest Parity (CIP). Klinger and Sundaresan (2019) and Boyarchenko, Gupta, Steele and Yen (2018) attribute to the same cause the fact that swap spreads have been low since the financial crisis and have recently turned negative for some contract maturities. Cenedese, Ranaldo and Vasios (2020) show that swap contracts that are bilaterally cleared, trade at a premium, relative to centrally cleared ones, due to higher regulatory costs (e.g., higher risk weights) that are passed on to clients via the so-called valuation adjustments (XVA). Ranaldo, Schaffner and Vasios (2021) show that prices for European repos drop during quarterly reporting periods when Basel III leverage ratio requirements constrain bank repo borrowing demand the most.

Similarly, recent evidence suggests that dealer balance sheet constraints can affect their trading activity. For instance, Kotidis and van Horen (2018) document reduced Sterling repo dealer volumes and Benos and Zikes (2018) document reduced gilt inter-dealer volumes as a result of tightened dealer balance sheets. Additionally, Acosta-Smith, Ferrara and Rodriguez-Tous (2018) find that such balance-sheet constrained dealers, acting as clearing members of CCPs, reduce the number of new clearing clients and also reduce the number of transactions that they clear for their existing clients. Overall, our results corroborate this literature and add that clearing arrangements are a key part of the collateral costs for dealers which are passed on to end-user investors via a basis.

Our analysis of the CCP basis further contributes to a larger literature that studies a non-zero basis in other contexts. For example, studies on the index-futures basis, the price differential between a market index and an accompanying index futures, include Miller, Muthuswamy and Whaley (1994), Kumar and Seppi (1994), and Dwyer, Locke and Yu (1996). More recent literature focuses on the CDS-bond basis which captures the price gap between a risk-free bond and a synthetic risk-free bond: a corporate bond plus a credit default swap (CDS) (e.g. Bai and Collin-Dufresne, 2019). The CCP basis differs from these types of bases in the sense that it is not driven by a classic "limit-to-arbitrage" friction, but a financial-architecture friction.

In sum, our analysis contributes to the literature by showing that clearing fragmentation is costly to dealers, a cost that is passed on to their clients. It suggests that the costs are non-trivial for hedging USD interest rates. We would like to emphasize that the data itself are part of our contribution to the literature. We are the first to have access to initial-margin data on interest-rate derivatives, an asset class where arguably most risk is exchanged globally.

We believe that our message on clearing fragmentation transcends the derivatives we study. Given that it must be true that many economic exposures of local investors are best hedged by trading with foreign investors who reside outside of their jurisdictions, we believe this fragmented-clearing friction is of first-order importance. We acknowledge that there are benefits to local CCPs (e.g., more regulatory oversight) but our analysis points out that the economic costs are non-trivial.

The paper proceeds as follows: Section 2 provides details on the institutional framework of centralized clearing. Section 3 describes the data, the hypotheses, the empirical models, and presents the results. Section 4 concludes. Additional robustness checks are included in the Appendix.

2 Institutional framework

2.1 Central clearing and initial margin

CCPs intermediate between the counterparties of a bilateral trade and become the buyer of the original seller, and the seller of the original buyer. By converting the bilateral exposures to exposures against the CCP, the original parties protect themselves against counterparty risk, i.e. the risk of losses due to counterparty default.

The reduction in counterparty risk comes at a cost, as CCPs require clearing members to post initial margin, daily, or sometimes even intra-day, to cover potential losses in the event of a clearing member default.[9] CCPs calculate initial margin using risk-based models, such as Value-at-Risk (VaR) or Standard Portfolio Analysis of Risk (SPAN). The calculated values of initial margin are a function of the riskiness and size of a given portfolio.

Margined portfolios may include contracts of various currencies and maturities and even contracts of different, but related, products. This means that any offsetting exposures in these contracts are netted prior to being margined and the contracts for which this is possible constitute a netting set. For example, LCH's SwapClear service includes IRS, FRA and OIS contracts in the same netting set. However, positions in different services within the same CCP (i.e. positions that are not in the same netting set) or positions in the same contracts cleared in different CCPs cannot be netted.

The G20 objective for more central clearing has been implemented in U.S. and Europe through the Dodd-Frank Act and the European Market Infrastructure Regulation (EMIR; regulation No 648/2012), respectively. In the U.S., central clearing of certain standardized IRS contracts has

[9] Clearing members are also required to make default fund contributions, which contribute towards the CCP's mutualized loss sharing arrangements. However, default fund contributions account for only a fraction (e.g., 5-6%) of the total funds available to the CCP in the event of a default. An example of the breakdown of a CCP's clearing member default resources, the so-called *default waterfall*, can be found here: https://www.lch.com/system/files/media_root/2a%20Default%20Waterfall%20Ltd%200.35%20200430%20SIG.pdf.

been mandatory for U.S. persons since March 2013. The EMIR clearing obligation was phased-in from June 2016 and required European counterparties of certain Over-The-Counter (OTC) interest rate derivatives to clear their transactions through an authorized CCP. As a result of the clearing obligation, the centrally-cleared segment of interest rate derivatives dominates trading during our sample period.[10]

2.2 Multilateral netting, clearing location, and clearing fragmentation

By novating all cleared trades (i.e., becoming the seller to every buyer and the buyer to every seller), CCPs enable their clearing members to net their exposures across counterparties for the purpose of margining. Multilateral netting thus allows clearing members to reduce their overall exposure versus the CCP, as well as the associated collateral cost. This is particularly beneficial for dealers in OTC derivatives markets whose gross positions are large but net positions tend to be small as a result of intermediating these trades.

This suggests that from a collateral saving point of view, it is optimal if all trades in the same or similar products are cleared via a single CCP.[11] However, clearing is often times fragmented across multiple CCPs. The main reason for this is a combination of regulatory constraints, given that these CCPs span multiple jurisdictions, as well as fixed costs associated with accessing a foreign CCP. In particular, there are regulatory mandates, in most jurisdictions, forcing local entities to clear their trades exclusively via local CCPs, largely because authorities wish to be in control of the clearing arrangements of local entities for supervisory and financial stability purposes.[12]

[10]For example, Cenedese et al. (2020) report that in 2015 90% of USD swap volumes and 85% of trades are centrally cleared.

[11]The fact that most EU-based asset managers and banks cleared their OTC derivatives trades via LCH in London, instead of their local CCPs, is a case in point. Another example highlighting the significance of netting efficiencies, in the choice of clearing location, is the fact that EUR-denominated repo transactions migrated en masse from LCH to EU-based CCPs in 2019, following a non-legally binding call by EU regulators, whereas EUR-denominated swap contracts did not. The difference between these two asset classes is that exposures in EUR-denominated repos are not netted against repo exposures in other currencies by LCH, and thus, the migration of EUR-denominated repos was not associated with the break-up of any netting sets. On the contrary, EUR-denominated swap exposures are netted against other currencies and any potential migration from London to EU-based CCPs, would have broken their netting sets. For more details on the migration of EUR repo trades, see here: https://www.reuters.com/article/us-britain-eu-clearing-idUSKCN1QA2EY.

[12]There are however ongoing initiatives between some jurisdictions with the aim of easing clearing access constraints. See for example the relevant discussions between Japanese and US authorities: https://www.risk.net/regulation/7726106/jfsa-pushes-for-jscc-to-clear-us-customer-trades

In the presence of these regulatory constraints, the only way to clear via a foreign CCP is by establishing foreign presence and booking any cleared trades on the balance sheet of the foreign branch. However, this is an option practically available only to the largest and most sophisticated market participants, typically those with global operations.

2.3 Clearing fragmentation in the USD IRS market

Clearing in the USD-denominated segment of the IRS market is dominated by two clearing houses, LCH and CME. LCH started clearing plain vanilla IRS, through its SwapClear platform, in 1999. It supports clearing in 27 currencies, some with tenors of up to 50 years. Its services are used by almost 100 financial institutions from over 30 countries, including all major dealers. CME began clearing OTC IRS contracts in 2010. It offers products in 19 currencies and has about 80 clearing members.

LCH has a market share in excess of 90% across all interest rate derivatives in USD, EUR and GBP, with these three currencies representing about 80% of SwapClear volumes.[13] It also clears approximately 55% of the USD IRS volumes with the rest being cleared by CME.[14] Thus, clearing in USD IRS contracts is fragmented, which makes it possible for a basis in the prices of these contracts to arise across the two CCPs (the CME-LCH basis).

3 Empirical analysis

3.1 Data

For our empirical analysis we use a variety of data primarily obtained from LCH and CME, covering the period between 1 January 2014 and 30 June 2016. To construct the CME-LCH basis in the USD interest rate swap market, we obtain, from both clearing houses, the yield curves used to price their derivatives contracts. These curves are extracted on a daily frequency for the full sample period and, as we explain in Section 3.2, they reflect dealers' quoted prices for trades cleared with each CCP.

[13] See `https://www.lch.com/services/swapclear/volumes`.

[14] See Clarus Financial Technology (2017).

The main body of our data consists of transactions on the full range of products cleared by LCH's SwapClear service, which includes IRS, FRA and OIS contracts, in the three main currencies (USD, EUR, and GBP). The transaction-level data contains information on contract and trade characteristics such as contract maturity, execution and effective dates, notional amounts traded, execution price (i.e., the contract fixed rate) but also information on counterparty identities. This allows us to identify individual dealer activity and also to observe the dealer-to-client segment of the market.[15]

In addition to the transactional data, we also utilize information on the daily amounts of initial margin posted by swap dealers on LCH. Initial margin is collected by LCH to cover losses in the event of a clearing member default and as such, it is calculated daily at the portfolio level using a filtered historical simulation approach.[16] We also obtain, from ClarusFT, daily volumes on dealers' switch trades in USD-denominated swap contracts.[17] Finally, we collect data, from Bloomberg, on dealers' CDS spreads and balance sheet characteristics as well as data on short-term USD funding costs.

3.2 The CME-LCH basis

The CME-LCH basis is the difference in the end-of-day settlement price between, same-maturity, USD-denominated, swap contracts cleared by CME and LCH. Here we reconstruct the CME-LCH basis using the same raw data that the two clearing houses use to calculate end-of-day settlement prices.

At this point it is important to describe how dealers' submitted data translate into a price differential in CCPs' settlement prices. At the end of each day, dealers communicate to the CCPs their quoted swap fixed rates for a number of different maturities. The CCPs then take an average of these quoted prices for each maturity and use them to back out the "zero coupon" yield curve

[15] We classify as dealers the financial institutions in the list of 16 "Participating Dealers" used by the OTC Derivatives Supervisors Group, chaired by the New York Fed. For more details see: https://www.newyorkfed.org/markets/otc_derivatives_supervisors_group.html.

[16] LCH's model uses 10 years of data to construct the empirical distribution of changes in portfolio values from which the potential loss distribution is calculated. For more details see https://www.lch.com/risk-management/risk-management-ltd.

[17] As we explain in more detail later on, switch trades are inter-dealer transactions aimed at reducing dealers' local imbalances.

associated with these maturities. The risk-free rates of the maturities for which dealers do not report swap price quotes, are interpolated from the extracted yield curve. The interpolated yield curve is then used to derive the settlement prices for any remaining maturities. Thus, any price differential in dealers' quoted prices ultimately shows up in CCPs' settlement prices.

From these yield curves, we calculate the IRS fixed rates using the standard swap pricing formula, applying the 3M/6M convention, whereby the floating payment is made every 3 months and the fixed payment every 6 months. Let $k \in \{LCH, CME\}$ denote one of the two CCPs. Equating the present values of the fixed and floating payment streams for a T-year contract and for CCP k, we have:

$$\sum_{i=1}^{2T} \frac{R_{k,t}^{fixed,6M,T}/2}{(1+\frac{R_{k,t,i}}{2})^i} = \sum_{j=1}^{4T} \frac{R_{k,t,j}^{floating,3M}/4}{(1+\frac{R_{k,t,j}}{4})^j} \tag{1}$$

where $R_{k,t}^{fixed,6M,T}$ is the day t annualized fixed rate of a T-year maturity contract cleared in CCP k, $R_{k,t,i}$ is the same-day annualized discount rate of period i, extracted by CCP k (i.e, CCP k's yield curve on day t) and $R_{k,t,j}^{floating,3M}$ is the period j forward rate of CCP k as of day t, extracted from the CCP's yield curve. Thus, the day t CME-LCH basis for a T-year contract is the difference between the two CCP T-year fixed rates as of that day. We calculate these bases for six different swap maturities, namely for 2, 3, 5, 7, 10, and 30-year contracts and use the simple average of these maturity-specific bases for our empirical analysis:

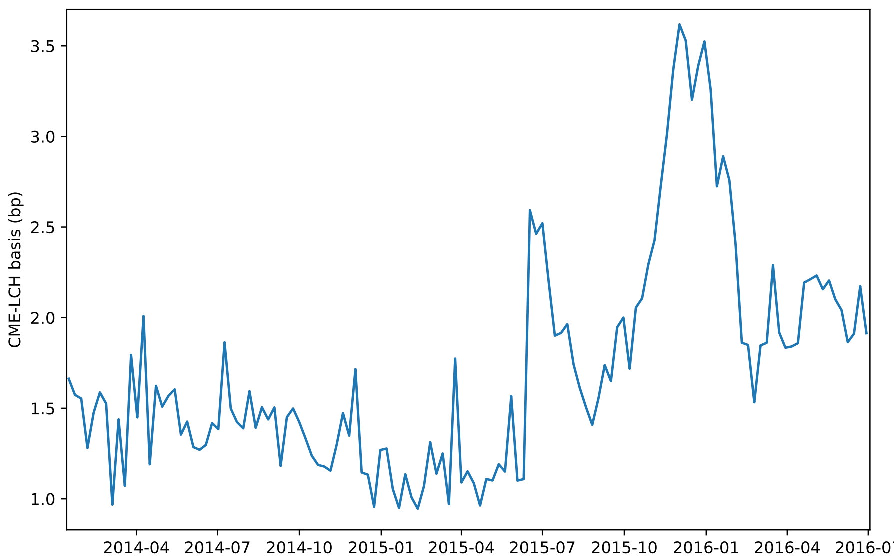
$$\textbf{CME} - \textbf{LCH Basis}_t \equiv \frac{1}{6} \sum_{T} \left(R_{CME,t}^{fixed,6M,T} - R_{LCH,t}^{fixed,6M,T} \right) \tag{2}$$

In Figure 2 we plot the average CCP basis, over our sample period, on a weekly frequency. As one can see, the average basis fluctuates between 1bp and 3.5bps. Furthermore, it substantially increases from June 2015.[18]

The CME-LCH basis is economically significant. For example, for an indicative average basis of

[18] The increase in the CCP basis could be associated with the phased-in implementation of the Basel III liquidity coverage ratio (LCR), which requires banks to hold high quality liquid assets (HQLAs) against their estimated 30 days' cash outflow. Initial margin is counted as cash outflow with a penalization of 20%, i.e., 1 unit of initial margin counting as 1.2 units of cash outflow. The LCR requirement became effective from Jan 1, 2015 at 60% rate and rose to 70% in 2016. This has likely further increased the cost of initial margin for dealers. See https://www.bis.org/bcbs/publ/d354.pdf.

Figure 2: Average CME-LCH basis (in bps) in USD-denominated IRS contracts as defined in equation (2). The time period is Jan 2014-Jun 2016.



1.7bps, LCH client sell (i.e. fixed rate receiving) trades in plain vanilla swaps, across all maturities, would be gaining approximately an additional \$80 million *daily* if they were to execute at CME-prevailing prices.[19]

3.3 Hypotheses

The economic intuition for a CCP basis that we developed in the introduction gives rise to a number of testable hypotheses. When dealers' outstanding inventories in each CCP are expected to be in the opposite direction, the basis should be a function of the per unit cost of collateral, asset volatility, the sum of expected outstanding inventories in the two CCPs and the fraction of market participants who are price-sensitive and can flexibly choose to clear in either CCP. Asset volatility times the outstanding dealer inventories is an approximation for the amount of collateral posted with each CCP, since, in practice, collateral (or initial margin) is typically calculated as the

[19] The average LCH daily client sell volume, in USD swap contracts, is \$48 billion during our sample period and the volume-weighted average maturity of these contracts is 9.7 years. Thus, a rough estimate of the cost to LCH sellers, associated with the basis, can be calculated as: $1.7bps \times 10^{-4} \times \$48bn \times 9.7 \approx \$80mn$. A similar calculation shows that the cost to LCH net selling clients would be around \$3 million daily.

Value-at-Risk (VaR) of the dealer's portfolio, which is a function of the portfolio's net notional and risk.

Additionally, the conflict of interest that may arise between the shareholders and senior creditors of dealer-banks, as articulated in Andersen et al. (2019), suggests that debt overhang should also affect the CCP basis. In particular, as the initial margin that a dealer pledges with CCPs is often funded with junior debt, a larger initial margin leads to an increase in the value of the dealer's senior debt and an associated decrease in the value of her equity. As a result, shareholders may seek to be compensated with a wider CCP basis. This effect is more pronounced when the dealer has higher credit risk, resulting in a positive relationship between dealer credit risk and the CCP basis.

Furthermore, given that longer-term contracts are riskier than shorter-term ones and attract a higher collateral cost, the above effects should be more pronounced for longer-maturity contracts than shorter-maturity ones.

Finally, our intuition suggests that if clients trade in a direction that minimizes (increases) dealers' imbalances, this will eventually lead to a reduction (increase) in the CCP basis. Thus, we state the following hypotheses:

H1: *The CME-LCH basis is increasing in dealers' posted collateral (initial margin) with LCH.*

H2: *The CME-LCH basis is decreasing in the LCH volume share of price-sensitive participants who can clear flexibly in multiple CCPs.*

H3: *The CME-LCH basis is increasing in the amount of debt overhang faced by dealers' shareholders and as such is increasing with dealers' credit risk.*

H4: *The above effects are more pronounced for longer-maturity contracts than shorter-maturity ones.*

H5: *Dynamically, the CME-LCH basis is decreasing in the amount of client net buy volume in USD swap contracts cleared in LCH.*

3.4 Determinants of the CME-LCH Basis

We next use our data to examine the determinants of the CME-LCH basis and also see whether our hypothesized predictions have empirical validity. We start by testing Hypotheses 1 - 3 using weekly time-series specifications. Our baseline time-series specification is:

$$Basis_t = a + b \cdot Collateral_t + c \cdot Flex\_Ratio_t + d \cdot Libor\_Spread_t + u_t \tag{3}$$

In this setup, *Basis* is the simple average of the end-of-week t value of the CME-LCH basis of each contract maturity as defined in equation (2).

Collateral captures the amount of collateral pledged by dealers and is either:

- the aggregate initial margin posted on LCH by all dealers or,
- the cumulative net volume in USD interest rate swap contracts transacted between dealers and their clients, or
- the expected Fed Funds rate which is calculated as:

  $$Exp\_Fed\_Funds = 100 - Fed\_Funds\_Futures \tag{4}$$

  where $Fed\_Funds\_Futures$ is the 1-month Fed Funds futures price.

The cumulative net dollar swap volume transacted by dealers is a proxy for the size of the dealers' aggregate inventory imbalance but also of dealers' inventory direction in LCH.[20] However, this variable is noisy because we do not observe dealers' initial positions and also because it does not capture the riskiness of the underlying swap positions. We nevertheless include it as a robustness check.[21]

[20] Intuitively, the CCP basis will arise when dealers' inventories across CCPs have opposite signs. Anecdotal evidence suggests that dealers' USD swap inventories in CME are negative. On the other hand, their cumulative net volume in LCH is positive throughout our sample period, which is consistent with the positive CCP basis that we observe.

[21] To account for inventory risk, one explanatory variable we used is the product of cumulative net dealer swap volume with measures of interest rate risk. These results are available upon request.

The expected Fed Funds rate is used as a proxy for the client buy flow (and associated order imbalance) in swap contracts cleared via CME. The intuition here is that as market participants expect short-term rates to rise, they have an additional incentive to purchase (i.e. to pay fixed in) USD swap contracts so as to lock in the lower prevailing rate. This client buy flow (assumed here to be primarily US-based) should then exacerbate the CME imbalance that dealers face and should further increase their collateral costs and ultimately the CME-LCH basis.[22] This variable also partially ameliorates the lack of data on dealer collateral and volumes cleared via CME.

For all three proxies, our intuition suggests that a relationship with the basis will exist *only* if dealer inventories across CCPs are of opposite sign. If inventories are of the same sign, then the implied basis should be zero and should not correlate with $Collateral$. Given that the CME-LCH basis is strictly positive, throughout our sample period, we indeed expect dealer inventories to have opposite signs across the two CCPs.

Flex_Ratio is the fraction of volume traded by non-dealer banks and is used as a proxy for the presence of market participants who can clear flexibly in either CCP. This is because all banks in our sample have access (through their subsidiaries) to both LCH and CME and thus can in principle clear through either CCP. This measure may not necessarily capture all market participants with access to both CCPs but it should account for the majority of flexible participants given that most non-bank entities (e.g., asset managers, hedge funds, etc.) typically only access (directly or indirectly) a single CCP.

Both the dealer initial margin, the dealer cumulative net swap volume and the activity by non-dealer banks pertain exclusively to LCH for which there is available data. In principle, the basis should also be a function of the collateral that the dealers post on CME and of the activity of non-dealer banks that is cleared through this CCP. However, given that dealers try to maintain balanced positions across CCPs, we suspect that any changes in dealer collateral posted in LCH would be highly correlated with changes in collateral posted with CME, to the extent that dealers' CME positions would be approximately offsetting to their LCH positions. Thus, the inclusion of

[22]Given that USD swap contracts can also be cleared on LCH, the underlying assumption here is that US-based market participants that clear via CME will be more responsive to changing expectations about the Fed Funds rate than non-US participants who would mainly clear via LCH.

LCH collateral alone in our empirical specification likely captures most of the effect induced by total collateral posted across both CCPs. For robustness, we also include in our specifications an imperfect proxy of US client buy flow (the expected Fed Funds rate) as discussed above.

Libor_Spread is used to proxy the funding cost faced by the dealers. It is the difference between the one-month USD Libor and one-month Treasury Bill rate and as such captures banks' aggregate credit risk.

To test Hypothesis 4, we first calculate a difference in bases between long- and short-maturity contracts, which is defined as:

$$BasisDiff_t \equiv (Basis\_7Y_t + Basis\_10Y_t + Basis\_30Y_t) - (Basis\_2Y_t + Basis\_3Y_t + Basis\_5Y_t) \quad (5)$$

where $Basis\_XY_t$ is the time t basis of contracts with a maturity of X years. This variable effectively captures the difference in average bases for contracts with more and less than five years to maturity. This variable is then conditioned on the same set of variables as the CCP basis itself. As such, our model is:

$$BasisDiff_t = a + b \cdot Collateral_t + c \cdot Flex\_Ratio_t + d \cdot Libor\_Spread_t + u_t. \quad (6)$$

Table 1 shows summary statistics for the time-series variables used in the above specifications. The aggregate CME-LCH basis fluctuates between 0.9-3.6bps with an average of 1.7bps. Total collateral posted by dealers on SwapClear is between euro 7-13.8 billions with an average amount of euro 11 billion. Finally, the fraction of volume that all dealers trade with other non-dealer banks is anywhere between 20%-60% with an average of 34%.

Table 2 shows the estimation results of specification (3). Our hypothesized predictions are supported in the data with the key variables having the expected signs and most being statistically significant. The proxies for the amount of dealers' posted collateral - the amount of initial margin posted by dealers on LCH, the dealers' cumulative net dollar swap volume and the expected Fed Funds rate - are positively associated with the CCP basis in most specifications.

The coefficient on the ratio of volume transacted with non-dealer banks is negative and signif-

Table 1: Summary statistics of the variables used in specification (3). *Basis* is the aggregate CME-LCH basis (in bps) is the simple average of the maturity-specific bases defined in equation (2) and *BasisDiff (bps)* is the difference in average bases for contracts with more and less than five years to maturity as defined in equation (5). *IM* is the aggregate initial margin posted with the SwapClear service of LCH by all dealers. *CumNetVlm* is the cumulative net dealer-to-client volume in USD interest rate swap contracts. *Exp_Fed_Funds* is an estimate of the expected Fed Funds rate and is defined in equation (4). *Flex_Ratio* is the fraction of volume across all SwapClear products that dealers transact with non-dealer banks. *Libor_Spread* is the difference between the one-month USD Libor and one-month Treasury Bill rates. All variables are weekly. The time period is January 2014 to June 2016.

	Mean	*Std*	*Min*	*Max*
Basis (bps)	1.72	.62	.95	3.62
BasisDiff (bps)	2.86	2.10	-0.45	8.68
IM (EUR bn)	11.06	1.80	7.11	13.75
CumNetVlm (USD bn)	186.66	179.83	-44.78	579.92
Exp_Fed_Funds (%)	0.18	0.11	0.07	0.43
Flex_Ratio	.34	.10	.20	.60
Libor_Spread (%)	.07	.02	.04	.17

icant, which is consistent with the intuition that location-flexible market participants will choose to clear where prices are keener and in doing so are likely to reduce local dealer imbalances and collateral costs, leading to a reduction in the CCP basis.

Finally, the Libor spread, while positive and significant in some specifications it is not invariably significant; this is likely because it is a noisy measure of the balance sheet costs faced by the dealers in our sample. In Section B of the Appendix however, we use dealer-specific risk and balance sheet information and thus provide more conclusive evidence in support of the debt overhang hypothesis.

Overall, these results suggest that the CCP basis is fundamentally a reflection of dealers' collateral costs and at the same time a means of compensation against these costs as originally hypothesized.[23,24]

Table 3 shows the estimation results of specification (6). The key explanatory variables maintain their signs and their significance (albeit with the exception of the expected Fed Funds rate), suggesting that the effects we identify are more pronounced for longer-maturity contracts than

[23] In the Appendix we also estimate this specification using a weighted average basis, with trading volumes of each of the contract maturities as weights. The key results remain unchanged.

[24] We have also estimated our model using end-of-quarter (i.e., financial-reporting-date) dummies in order to account for potential effects on the CCP basis arising from dealer regulatory constraints. We find no significant effects during reporting periods and our main explanatory variables retain their significance. These results are available upon request.

shorter-maturity ones. If our intuition about the CCP basis is correct, this is to be expected since longer-maturity contracts are more collateral-intensive as a result of their higher sensitivity to interest rate risk.

3.5 Dynamic effects on the CME-LCH basis

Dealers set higher (lower) prices where there is persistent client buy (sell) flow. They do this because they want to recoup the collateral costs associated with maintaining imbalanced inventories in each CCP. Thus, as stated in Hypothesis 5, we predict that the basis will respond over time to client flow in the USD IRS market with the basis increasing (decreasing) whenever clients sell (buy) USD swap contracts in LCH. In this section we test this hypothesis using a Vector Auto-Regression model with exogenous variables (VARX). Our model takes the following form:

$$\mathbf{y}_t = a + \sum_{i}^{3} (\mathbf{C}_i \mathbf{y}_{t-i} + d_i X_{t-i}) + u_t, \quad u \sim (\mathbf{0}, \Sigma) \tag{7}$$

where t denotes weeks, $\mathbf{y}_t$ is the vector of endogenous variables and X_{t-1} is a vector of exogenous variables. The endogenous variables are:

$$\mathbf{y}_t = \begin{bmatrix} Flex\_Ratio_t \\ IRS\_Net\_Vlm_t \\ IM_t \\ Basis_t \end{bmatrix}$$

where IRS_Net_Vlm is the client net (i.e. buy minus sell) volume of USD-denominated IRS contracts, cleared in LCH. The rest of the endogenous variables are the same as the ones used in our time series regressions. ΔExp_Fed_Funds is treated as exogenous, as it is not affected by the other variables. The number of lags in the model is determined by the Schwarz Information Criterion (SIC).

To identify our model we apply short-term restrictions (via a Cholesky decomposition) treating $Flex\_Ratio$ as the most exogenous variable and the basis as the most endogenous one. This ordering

Table 2: Estimation results of the basis time-series model (3). The dependent variable is the CME-LCH basis defined in equation (2). *IM* is the aggregate dealer initial margin posted with LCH, *CumNetVlm* is the cumulative net dealer-to-client volume in USD interest rate swap contracts, *Exp_Fed_Funds* is an estimate of the expected Fed Funds rate and is defined in equation (4) and *Flex_Ratio* is the fraction of volume across all SwapClear products that dealers transact with non-dealer banks. *Libor_Spread* is the difference between the one-month USD Libor and one-month Treasury Bill rates. Robust (Newey-West) t-statistics are in parentheses. *, ** and *** denote significance at 10%, 5% and 1% respectively. The time period is January 2014 to June 2016.

	(1) Basis	(2) Basis	(3) Basis	(4) Basis	(5) Basis	(6) Basis	(7) Basis	(8) Basis
IM	0.1406***					0.1279***		
	(4.36)					(4.05)		
CumNetVlm		0.0023***					0.0022***	
		(6.68)					(6.83)	
Δ*Exp_Fed_Funds*			12.1029**					11.9232**
			(2.02)					(2.20)
Flex_Ratio				-1.9923***		-1.6224***	-0.5480	-2.0373***
				(-3.58)		(-2.86)	(-1.30)	(-3.97)
Libor_Spread					5.6159***			
					(3.05)			
cons	0.1606	1.2989***	1.6923***	2.3990***	0.7926**	0.8524**	1.5035***	2.3803***
	(0.51)	(25.62)	(24.81)	(10.44)	(2.43)	(2.51)	(9.95)	(11.63)
R^2	0.174	0.446	0.074	0.094	0.166	0.235	0.452	0.170
N	130	130	128	130	130	130	130	128

Table 2 continued

	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	Basis	Basis	Basis	Basis	Basis	Basis	Basis
IM	0.0836			0.1370***		0.0856	
	(1.28)			(4.95)		(1.47)	
CumNetVlm		0.0026***			0.0021***		0.0025***
		(3.94)			(7.32)		(4.32)
ΔExp_Fed_Funds			13.0969**	10.3304**	9.2055**	11.6295***	8.3591**
			(2.42)	(2.37)	(2.30)	(2.67)	(2.37)
Flex_Ratio	-1.5259***	-0.4285	-1.6304***	-1.7398***	-0.6643	-1.6085***	-0.5745
	(-2.73)	(-0.97)	(-3.18)	(-3.19)	(-1.56)	(-3.03)	(-1.29)
Libor_Spread	3.0033	-2.3020	5.3471***			3.1939	-1.8062
	(0.98)	(-0.80)	(3.21)			(1.17)	(-0.70)
cons	0.8143***	1.7625***	1.3538***	0.7523**	1.5171***	0.7505**	1.7209***
	(2.72)	(4.76)	(3.52)	(2.41)	(9.81)	(2.61)	(5.22)
R^2	0.264	0.465	0.316	0.320	0.513	0.351	0.520
N	130	130	128	128	128	128	128

Table 3: Estimation results of the basis time-series model (6). The dependent variable is the difference between the long and short maturity bases defined in (5). *IM* is the aggregate dealer initial margin posted with LCH, *CumNetVlm* is the cumulative net dealer-to-client volume in USD interest rate swap contracts, *Exp_Fed_Funds* is an estimate of the expected Fed Funds rate and is defined in equation (4) and *Flex_Ratio* is the fraction of volume across all SwapClear products that dealers transact with non-dealer banks. *Libor_Spread* is the difference between the one-month USD Libor rate and the one-month Treasury Bill rate. Robust (Newey-West) t-statistics are in parentheses. *, ** and *** denote significance at 10%, 5% and 1% respectively. The time period is January 2014 to June 2016.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	BasisDiff	BasisDiff	BasisDiff	BasisDiff	BasisDiff	BasisDiff	BasisDiff	BasisDiff
IM	0.6413***					0.5834***		
	(6.75)					(6.49)		
CumNetVlm		0.0093***					0.0086***	
		(10.39)					(10.05)	
Δ*Exp_Fed_Funds*			15.1860					14.4029
			(0.87)					(0.90)
Flex_Ratio				-9.0724***		-7.3851***	-3.3226***	-8.8758***
				(-5.72)		(-4.61)	(-3.12)	(-5.72)
Libor_Spread					23.8095***			
					(4.09)			
cons	-4.2589***	1.1402***	2.8649***	5.9458***	-1.0769	-1.1101	2.3810***	5.8623***
	(-4.63)	(6.85)	(11.11)	(8.90)	(-1.06)	(-1.05)	(5.50)	(9.04)
R^2	0.306	0.626	0.010	0.166	0.252	0.413	0.646	0.167
N	130	130	128	130	130	130	130	128

Table 3 continued

	(9)	(10)	(11)	(12)	(13)	(14)	(15)
	BasisDiff	BasisDiff	BasisDiff	BasisDiff	BasisDiff	BasisDiff	BasisDiff
IM	0.4243***			0.5978***		0.4174**	
	(2.64)			(6.45)		(2.47)	
CumNetVlm		0.0099***			0.0086***		0.0100***
		(7.16)			(10.04)		(6.94)
Δ*Exp_Fed_Funds*			19.1656	7.4539	3.4702	12.0076	0.2678
			(1.35)	(0.67)	(0.45)	(1.10)	(0.04)
Flex_Ratio	-7.0382***	-2.9698***	-7.2248***	-7.5782***	-3.3529***	-7.1179***	-3.0129**
	(-4.67)	(-2.62)	(-5.02)	(-4.71)	(-3.05)	(-4.71)	(-2.58)
Libor_Spread	10.7865	-6.7968	21.6987***			11.1949	-6.8342
	(1.38)	(-1.06)	(3.89)			(1.42)	(-1.03)
cons	-1.2469	3.1457***	1.6968	-1.2398	2.3900***	-1.2461	3.1613***
	(-1.28)	(3.79)	(1.41)	(-1.16)	(5.45)	(-1.23)	(3.74)
R^2	0.445	0.655	0.373	0.411	0.641	0.444	0.650
N	130	130	128	128	128	128	128

is based on the intuition that structural flow imbalances in each CCP should increase dealers' initial margin, which then should give rise to a CCP basis in the USD swap market. However, the results of the VAR model are not sensitive to the particular ordering that we choose.

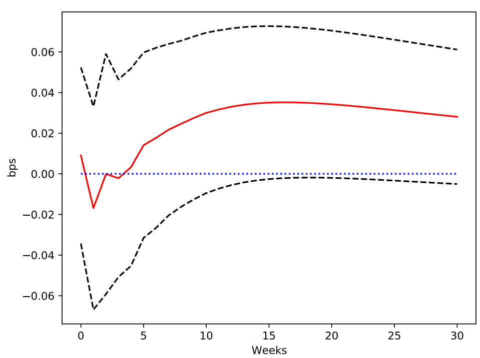
Figure 3 shows impulse response functions calculated from the estimated coefficients of model (7). Charts (a), (b) and (c) show the impulse responses of the CME-LCH basis to shocks in dealers' posted margin on LCH (IM), the first difference of our proxy for dealers' order imbalance on CME (ΔExp_Fed_Funds) and the fraction of client volume traded with non-dealer banks ($Flex\_Ratio$). These responses corroborate the findings of the time-series regressions; they show that both IM and ΔExp_Fed_Funds have positive impacts on the CCP basis whereas $Flex\_Ratio$ has a negative one. Chart (d) shows the response of the basis to a shock in client net volume in USD swaps cleared via LCH and provides a test for Hypothesis 5. The chart shows that when client net volume is positive, the CME-LCH basis decreases. In other words, when clients trade in a direction that reduces dealers' imbalance in LCH, the CME-LCH basis shrinks and vice versa. This is consistent with the economic intuition that dealers use the basis to recoup their collateral costs.[25]

3.6 Dealer switch trades

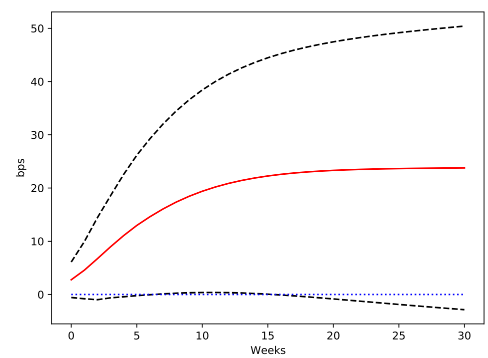
Given the collateral costs associated with fragmented clearing, dealers have begun in the past few years to engage in *switch trades* in an attempt to reduce these costs. A switch trade involves the simultaneous buy and sell, between two dealers, of the same quantity of a given contract, in two different CCPs, with the purpose of reducing local imbalances and thus collateral costs. To illustrate, suppose a dealer has a net short exposure in swap contracts in CME and a net long exposure in LCH. Suppose further that a second dealer has the exact opposite positions, with a net long exposure in CME and a net short one in LCH. In this scenario, the first dealer can buy swaps from the second dealer in CME and at the same time sell that dealer the same amount of swaps in LCH. These two trades will reduce the imbalances of both dealers in CME and LCH without

[25]It is worth noting that the effect of IM on the CME-LCH basis, as shown in chart (a), is longer-lasting than those of the other endogenous variables in charts (c) and (d). One potential reason for this is that IM is a function of both dealers' local exposures as well as the volatility of these exposures, whereas the other impulse variables only affect the size of dealers' exposures. The longer-lasting effect of IM could then be driven by the persistence that volatility typically exhibits.

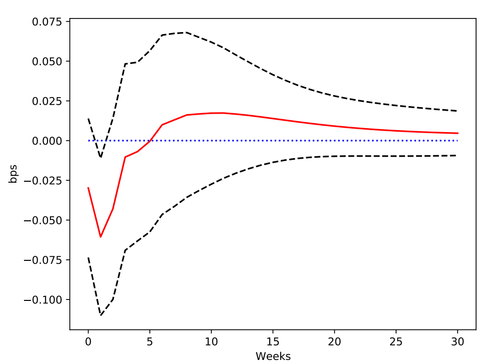
Figure 3: Impulse response functions obtained from estimating model (7). *Basis (in bps)* is the CME-LCH basis as defined in equation (2). *IM* is the total initial margin posted by swap dealers on LCH, *Flex_Ratio* is the fraction of volume across all SwapClear products that dealers transact with non-dealer banks, *Exp_Fed_Funds* is an estimate of the expected Fed Funds rate and is defined in equation (4) and *IRS_Net_Vlm* is the client net (i.e. buy minus sell) volume in USD interest rate swap contracts cleared in LCH. The dotted lines show the 95% confidence intervals of the estimated impulse responses. The horizontal axes represent weeks and the plots show responses to one-standard-deviation shocks in the impulse variables. The time period is January 2014 to June 2016.



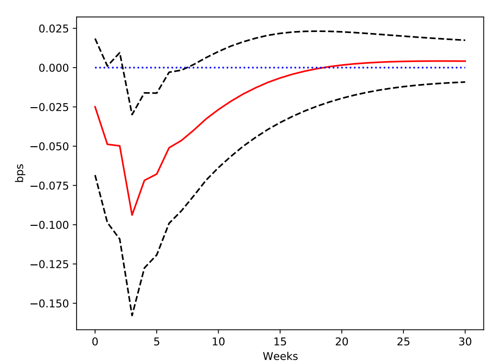
(a) Impact of *IM* on *Basis*



(b) Impact of Δ*Exp_Fed_Funds* on *Basis*



(c) Impact of *Flex_Ratio* on *Basis*



(d) Impact of *IRS_Net_Vlm* on *Basis*

affecting their respective overall portfolio exposures or risk.

These switch trades then suggest two additional hypotheses:

H6: *Dealer switch trade volume will respond positively to dealers' collateral cost as captured by their posted collateral.*

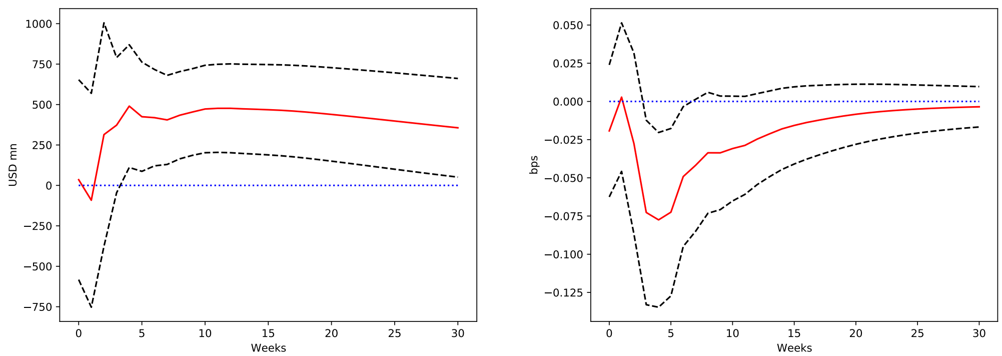
H7: *Dynamically, the CME-LCH basis is decreasing in dealers' switch trade volume.*

The first hypothesis simply tests whether switch trades become more likely when dealer collateral costs become higher. If switch trades then allow dealers to reduce their local imbalances, this should translate into a lower CME-LCH basis, which is what the second hypothesis tests.

We obtain data on switch trade volumes from ClarusFT and use it in our VARX model (7).[26] Figure 4 depicts the impulse response functions associated with the above hypotheses. The left plot shows that, indeed, dealers' switch trade volume increases after a shock to dealers' posted collateral. The right plot confirms that a shock to switch trade volume is followed by a reduction in the CME-LCH basis.

[26] We do that by replacing the *IRS_Net_Vlm* variable with dealers' switch trade volume.

Figure 4: Impulse response functions obtained from estimating model (7) where the *IRS_Net_Vlm* variable has been replaced by *Switch_Vlm*. *Switch_Vlm (in USD million)* is the trading volume of switch trades executed by swap dealers. *Basis (in bps)* is the CME-LCH basis as defined in equation (2). *IM* is the total initial margin posted by swap dealers on LCH. The dotted lines show the 95% confidence intervals of the estimated impulse responses. The horizontal axes represent weeks and the plots show responses to one-standard-deviation shocks in the impulse variable. The time period is January 2014 to June 2016.



(a) Impact of *IM* on *Switch_Vlm* (b) Impact of *Switch_Vlm* on *Basis*

3.7 Alternative explanations for the CME-LCH basis

We argue that the CME-LCH basis is driven by fragmented clearing between the two CCPs. However, given that the two CCPs differ in several ways, one could argue that the basis might also be driven by other factors, not captured in our analysis. Below we discuss various candidate factors.

- *CCPs' margin models*: For standard derivatives contracts, the margining models are generally fairly homogeneous. That said, there may still be differences in the margin models across the two CCPs, especially in the calculation of margin add-ons such as concentration charges.[27] Such differences would affect the collateral cost associated with a local CCP exposure and could therefore contribute to the CCP basis. Given that we only use collateral data from LCH, our empirical model likely does not accurately capture any such differences. However, by including the amount of collateral pledged in LCH and showing that it correlates with the CME-LCH basis, we are able to demonstrate that collateral costs matter for the CCP bases,

[27] Duffie, Scheicher and Vuillemey (2015) offers some insight into CCP margin requirements for credit default swaps but exact parameters of CCPs' margin models and margin add-ons are not publicly available.

which is our basic premise.

- *CCPs' default fund requirements*: The two CCPs may also differ in the requirements they impose on their clearing members as far as their default fund contributions are concerned.[28] However, we think it is unlikely that any such differences alone could explain all of our empirical results on the CME-LCH basis. The reason for that is that default fund contributions are calibrated to a "Cover 2" standard using historical stressed scenarios. As such, default fund contributions have very little time variability which cannot explain the high-frequency variability that we observe in the CME-LCH basis.

- *Clearing fees*: Clearing fees may differ across CCPs but we do not believe they could explain our results for two reasons: First, the fee difference between CME and LCH is too low to justify the CME-LCH basis. For example, for a $10 million notional trade in a 5-year IRS contract, LCH charges a $54 initial booking fee and an annual $30 maintenance fee,[29] whereas CME charges a $45 booking fee and an annual $20 maintenance fee.[30] These fee schedules suggest that the cost difference between CME and LCH in executing a $10 million trade, is around $50 (with future payments being discounted at a zero rate). This, however, is two orders of magnitude smaller than the opportunity cost associated with an average basis of 1.68bps (for the 5-year IRS), which is around $8,400.[31] Second, it is more likely that any trading cost differences related to fees would be recouped by dealers via the bid-ask spread and not the CME-LCH basis, given that the fees are not directional (i.e., they apply equally to buy and sell trades). On the contrary, collateral costs which we feature as the key driver of the basis are directional (i.e., these costs could be reduced if trades reduce the extent of offsetting positions across CCPs).

[28] For an in-depth discussion on CCP default fund structure and loss allocation rules, we refer to Raykov (2016).
[29] https://www.lch.com/services/swapclear/fees
[30] https://www.cmegroup.com/trading/interest-rates/cleared-otc-irs-customer-fees.html
[31] 1.68 basis points $\times$ 5 years $\times$ 1000.

4 Conclusion

With central clearing having become a key feature of OTC derivatives markets, after the 2007-08 financial crisis, questions regarding the scope and size of CCPs are becoming increasingly important. Our paper sheds light on such a question, namely what happens when clearing in comparable products is fragmented across multiple CCPs. In this context, we document an economically significant price differential between essentially identical USD interest-rate derivatives cleared in CME and LCH (the CME-LCH basis) and argue that this is a result of dealers seeking compensation for bearing increased collateral costs when clearing is fragmented.

More generally, our paper highlights the emerging importance of the post-trade cycle (which includes clearing and settlement) for asset pricing. Technological and regulatory developments in this area have changed (and are likely to continue to change) the institutional arrangements under which securities and financial contracts have traditionally been traded. Understanding then the impact of these changes on asset prices, is a fruitful area of further research and one with potentially important policy implications.

Appendix

In the Appendix we present the result of some additional empirical tests that provide further support to our main results.

A Volume-weighted average basis

We first re-estimate model (3), using a volume-weighted average basis as dependent variable. We do this to ensure that our results are not primarily driven by the bases of thinly traded contracts which would have reduced the economic significance of our findings. For this, we weigh the maturity-specific CME-LCH bases using the global trading volumes of the underlying interest rate swap contracts and re-estimate model (3). The results are shown in Table 4 and it is evident that the signs and statistical significance of the key variables remain unchanged.

B Dealer effects

In this section we identify determinants of the CCP basis utilizing dealer-specific information. Given that we observe dealer-specific trades on LCH, we first define a proxy for the dealer-specific bases using individual dealers' LCH execution prices. Unfortunately, we do not observe individual dealer activity on CME, so we cannot compare dealers' LCH prices with their CME ones. Instead, we compare dealers' LCH prices with a common benchmark, namely the end-of-day CME settlement price. Thus, our proxy for dealer's d basis for a T-year contract, on day t, is defined as:

$$\textbf{CME} - \textbf{LCH Dealer Basis}_t^d \equiv R_{CME,t}^{fixed,6M} - \bar{R}_{LCH,t}^{fixed,6M,d} \tag{A1}$$

where $R_{CME,t}^{fixed,6M}$ is the average (across maturities) fixed rate of USD swap contracts cleared via CME and $\bar{R}_{LCH,t}^{fixed,6M,d}$ is the day t volume-weighted average execution price (across all USD swap contracts), of dealer d on LCH.

We then use these dealer-specific bases to estimate the following panel regression model with dealer fixed effects:

$$DealerBasis_{dt} = a + b \cdot IM_{dt} + c \cdot Flex\_Ratio_{dt} + d \cdot CreditRisk_{dt} + v_d + u_{dt}, \qquad \text{(A2)}$$

where d denotes dealers and t denotes weeks. Most of the variables are the same as the ones used in the time-series specification except that they are now calculated at a dealer level. As such, $DealerBasis_{dt}$ is the dealer-specific CCP basis as defined in equation (A1), IM_{dt} is the dealer-specific amount of initial margin posted with LCH and $Flex\_Ratio_{dt}$ is the dealer-specific fraction of traded volume with non-dealer banks. To test the debt overhang hypothesis, we include, in the specification, variables intended to capture individual dealers' credit risk. As such, $CreditRisk_{dt}$ is either each dealer's 5-year CDS spread (or that of their parent company) or their equity ratio, defined as the market value of equity over the book value of assets. The model is estimated using dealer-specific fixed effects to account for unobservable, time-invariant, heterogeneity across dealers.

Summary statistics for the panel variables used in the above specification are shown in Table 5. The average dealer-specific basis is around 1bps but fluctuates substantially and for some dealer-weeks also turns negative. On average, each dealer posts around euro 0.46 billion of collateral with SwapClear-LCH at any given week, but there is substantial variation across dealer-weeks with a minimum of around euro 10,000 and a maximum of euro 2.5 billion. Similarly, the other activity variables also exhibit higher variability than their aggregated time-series counterparts, reflecting differences across dealers.

The results of various regressions nested in specification (A2) are shown in Table 6. All the main hypotheses continue to be supported in the data with IM, $Flex\_Ratio$ and $Libor\_Spread$ having the expected signs. Furthermore, our results are consistent with the debt overhang hypothesis in Andersen et al. (2019), as dealer CDS spreads (equity ratios) are positively (negatively) associated with our proxy for the dealer-specific basis. In other words, as dealers' credit risk increases and debt overhang becomes more pronounced, the equity holders of those dealer banks require a higher compensation, in the form of the CCP basis, to compensate the wealth transfer accruing to senior creditors, when additional collateral is posted to the clearing house.

Table 4: Estimation results of the basis time-series model (6) using the volume-weighted average basis as a dependent variable. *IM* is the aggregate dealer initial margin posted with LCH, *CumNetVlm* is the cumulative net dealer-to-client volume in USD interest rate swap contracts, *Exp_Fed_Funds* is an estimate of the expected Fed Funds rate and is defined in equation (4) and *Flex_Ratio* is the fraction of volume across all SwapClear products that dealers transact with non-dealer banks. *Libor_Spread* is the difference between the one-month USD Libor rate and the one-month Treasury Bill rate. Robust (Newey-West) t-statistics are in parentheses. *, ** and *** denote significance at 10%, 5% and 1% respectively. The time period is January 2014 to June 2016.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	BasisVW	BasisVW	BasisVW	BasisVW	BasisVW	BasisVW	BasisVW	BasisVW
IM	0.1269***					0.1180***		
	(3.91)					(3.71)		
CumNetVlm		0.0020***					0.0020***	
		(6.08)					(6.24)	
Δ*Exp_Fed_Funds*			10.6800*					10.5395**
			(1.92)					(2.05)
Flex_Ratio				-1.4845***		-1.1433**	-0.1557	-1.5932***
				(-2.77)		(-2.14)	(-0.38)	(-3.23)
Libor_Spread					4.8314***			
					(2.70)			
cons	0.2541	1.2865***	1.6331***	2.1685***	0.8644***	0.7416**	1.3447***	2.1711***
	(0.77)	(25.70)	(25.54)	(9.80)	(2.76)	(2.25)	(8.91)	(10.86)
R^2	0.157	0.393	0.064	0.058	0.136	0.190	0.394	0.130
N	130	130	128	130	130	130	130	128

Table 4 continued

	(9) BasisVW	(10) BasisVW	(11) BasisVW	(12) BasisVW	(13) BasisVW	(14) BasisVW	(15) BasisVW
IM	0.0826			0.1313***		0.0942*	
	(1.30)			(4.94)		(1.73)	
CumNetVlm		0.0025***			0.0020***		0.0024***
		(3.85)			(6.61)		(4.30)
Δ*Exp_Fed_Funds*			11.5656**	9.0128**	8.0165**	9.9502**	6.9214**
			(2.31)	(2.19)	(2.20)	(2.53)	(2.23)
Flex_Ratio	-1.0661**	-0.0208	-1.2374**	-1.3081**	-0.3186	-1.2133**	-0.2024
	(-1.98)	(-0.05)	(-2.50)	(-2.60)	(-0.79)	(-2.40)	(-0.48)
Libor_Spread	2.3994	-2.6002	4.6750***			2.3045	-2.3370
	(0.81)	(-0.95)	(2.78)			(0.88)	(-0.95)
cons	0.7111**	1.6372***	1.2737***	0.6108**	1.3698***	0.6095**	1.6336***
	(2.40)	(4.55)	(3.31)	(2.10)	(8.88)	(2.22)	(5.08)
R^2	0.211	0.411	0.254	0.283	0.459	0.301	0.472
N	130	130	128	128	128	128	128

Table 5: Summary statistics, over dealer-weeks, of the panel variables used in specification (A2). $DealerBasis_{it}$ is the dealer-specific CCP basis as defined in equation (A1). *IM* is the initial margin posted with the SwapClear service of LCH by each dealer. *Flex_Ratio* is the fraction of total client volume, across all SwapClear products, that each dealer transacts with non-dealer banks. *CDS* is the dealer 5-year CDS spread and *Equity* is dealer ratio of market value of equity over book value of assets. The time period is January 2014 to June 2016.

	Mean	*Std*	*Min*	*Max*	*N*	*Frequency*
DealerBasis (bps)	.99	1.37	-3.89	7.11	2722	Weekly
IM (EUR bn)	.46	.32	.0001	2.50	2778	Weekly
RatioFlex	.47	.27	0	1	3120	Weekly
CDS spreads (bps)	77.54	22.01	34.90	234.7	1810	Weekly
Equity	0.06	0.04	0.01	0.17	1806	Quarterly

Table 6: Estimation results of the dealer basis panel model (A2). The dependent variable is the proxy for the dealer-specific CME-LCH basis defined in equation (A1). *IM* is the individual dealer initial margin posted with LCH and *Flex_Ratio* is the fraction of volume across all SwapClear products that each dealer transacts with non-dealer banks. *Libor_Spread* is the difference between the one-month USD Libor rate and the one-month Treasury Bill rate. *CDS* is the CDS spread and *Equity* is the market value of equity over the book value of assets of either the individual dealer itself or of the dealer's parent company. Robust t-statistics are in parentheses. *, ** and *** denote significance at 10%, 5% and 1% respectively. The time period is January 2014 to June 2016.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	DealerBasis	DealerBasis	DealerBasis	DealerBasis	DealerBasis	DealerBasis	DealerBasis	DealerBasis	DealerBasis
IM	1.5228***					1.4425***	1.4282***	1.1179***	0.6463**
	(4.13)					(3.65)	(3.89)	(3.29)	(2.41)
Flex_Ratio		-0.7061***				-0.3930	-0.5399*	-0.5423**	-0.3561**
		(-2.96)				(-1.69)	(-1.98)	(-2.52)	(-2.43)
CDS			0.0175***			0.0148***		0.0156***	0.0087***
			(4.16)			(3.86)		(3.89)	(3.31)
Equity				-36.0861***			-26.9507***	-12.5804	-2.2909
				(-4.25)			(-3.06)	(-1.21)	(-0.27)
Libor_Spread					14.2000***				10.3408***
					(32.62)				(7.61)
cons	0.2842	1.3220***	-0.4285	3.2075***	-1.3663***	-0.7103**	2.2214***	0.3011	-1.4213
	(1.62)	(11.96)	(-1.31)	(6.05)	(-18.88)	(-2.61)	(3.41)	(0.29)	(-1.63)
R^2	0.045	0.008	0.062	0.056	0.217	0.104	0.104	0.130	0.215
N	2585	2722	1736	1733	2722	1655	1652	1468	1468

References

Acosta-Smith, J., Ferrara, G., Rodriguez-Tous, F., 2018. The impact of leverage ratio on client clearing. Bank of England Staff Working Paper No. 735 .

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

Andersen, L., Duffie, D., Song, Y., 2019. Funding value adjustments. Journal of Finance 74, 145–192.

Bai, J., Collin-Dufresne, P., 2019. The cds-bond basis. Financial Management 49, 417–439.

Benos, E., Zikes, F., 2018. Funding constraints and liquidity in two-tiered OTC markets. Journal of Financial Markets 39, 24–43.

Boyarchenko, N., Gupta, P., Steele, N., Yen, J., 2018. Negative swap spreads. Federal Reserve Bank of New York Economic Policy Review 24.

Cenedese, G., Corte, P.D., Wang, T., 2021. Currency mispricing and dealer balance sheets. Journal of Finance 76, 2763–2803.

Cenedese, G., Ranaldo, A., Vasios, M., 2020. OTC premia. Journal of Financial Economics 136, 86–105.

Du, W., Tepper, A., Verdelhan, A., 2018. Deviations from covered interest rate parity. Journal of Finance 73, 915–957.

Duffie, D., Scheicher, M., Vuillemey, G., 2015. Central clearing and collateral demand. Journal of Financial Economics 116, 237–256.

Duffie, D., Zhu, H., 2011. Does a central clearing counterparty reduce counterparty risk? Review of Asset Pricing Studies 1, 74–95.

Dwyer, G.P., Locke, P., Yu, W., 1996. Index arbitrage and nonlinear dynamics between the s&p 500 futures and cash. Review of Financial Studies 9, 301–332.

Fleckenstein, M., Longstaff, F.A., 2020. Renting balance sheet space: Intermediary balance sheet rental costs and the valuation of derivatives. Review of Financial Studies 33, 5051–5091.

Fleming, M., Rosenberg, J., 2008. How do Treasury Dealers Manage their Positions? Technical Report. FRB of New York Staff Report No. 299.

Friewald, N., Nagler, F., 2019. Over-the-counter market frictions and yield spread changes. Journal of Finance , 3217–3257.

Garleanu, N., Pedersen, L.H., 2011. Margin-based asset pricing and deviations from the law of one price. Review of Financial Studies 24, 1980–2022.

Garratt, R., Zimmerman, P., 2020. Centralized netting in financial networks. Journal of Banking and Finance 112, 1–16.

Hendershott, T., Menkveld, A.J., 2014. Price pressures. Journal of Financial Economics 114, 405–423.

Ho, T., Stoll, H.R., 1981. Optimal dealer pricing under transaction cost and return uncertainty. Journal of Financial Economics 9, 47–73.

Klinger, S., Sundaresan, S., 2019. An explanation of negative swap spreads: Demand for duration from underfunded pension plans. Journal of Finance 74, 675–710.

Kotidis, A., van Horen, N., 2018. Repo market functioning: The role of capital regulation. Bank of England Staff Working Paper No. 746 .

Kumar, P., Seppi, D.J., 1994. Information and index arbitrage. Journal of Business 67, 481–509.

Menkveld, A.J., Vuillemey, G., 2021. The economics of central clearing. Annual Review of Financial Economics 13, 153–178.

Miller, M.H., Muthuswamy, J., Whaley, R.E., 1994. Mean reversion of standard & poor's 500 index basis changes: Arbitrage-induced or statistical illusion? Journal of Finance 49, 479–513.

Naik, N.Y., Yadav, P.K., 2003. Do dealer firms manage inventory on a stock-by-stock or a portfolio basis? Journal of Financial Economics 69, 325–353.

Ranaldo, A., Schaffner, P., Vasios, M., 2021. Regulatory effects on short-term interest rates. Journal of Financial Economics 141, 750–770.

Randall, O., 2015. How Do Inventory Costs Affect Dealer Behavior in the US Corporate Bond Market? Technical Report. Emory University.

Raykov, R.S., 2016. To Share or Not to Share? Uncovered Losses in a Derivatives Clearinghouse. Manuscript. Bank of Canada.

Schultz, P., 2017. Inventory Management by Corporate Bond Dealers. Technical Report. University of Notre Dame.

Sidanius, C., Zikes, F., 2012. OTC derivatives reform and collateral demand impact. Bank of England Financial Stability paper No. 18 .

Singh, M., 2009. Collateral, netting, and systemic risk in the otc derivatives market. IMF working paper 10/99 .

Singh, M., 2013. New regulations and collateral requirements - implications for the otc derivatives market. SWIFT Institute working paper 2012-004 .

Clarus Financial Technology, 2017. CCP market share statistics. https://www.clarusft.com/2017-ccp-market-share-statistics/ .