School of Finance

University of St.Gallen

OTC PREMIA

GINO CENEDESE
ANGELO RANALDO
MICHALIS VASIOS

WORKING PAPERS ON FINANCE NO. 2018/18
FORTHCOMING IN JOURNAL OF FINANCIAL ECONOMICS

SWISS INSTITUTE OF BANKING AND FINANCE (S/BF – HSG)

DECEMBER 9, 2018
THIS DRAFT: MAY 2019

OTC Premia*

Gino Cenedese[†] Angelo Ranaldo[‡] Michalis Vasios[§]

This draft: May 2019

Forthcoming in Journal of Financial Economics

Abstract

Using unique data at transaction and identity levels, we provide the first systematic study of interest rate swaps traded over the counter (OTC). We find substantial and persistent heterogeneity in derivative prices consistent with a pass-through of regulatory costs on to market prices via so-called valuation adjustments (XVA). A client pays a higher price to buy interest rate protection from a dealer (i.e., the client pays a higher fixed rate) if the contract is not cleared via a central counterparty. This OTC premium decreases by posting initial margins and with higher buyer's creditworthiness. OTC premia are absent for dealers suggesting bargaining power.

Keywords: Interest rate swaps, Financial regulation, Central clearing, Over-the-counter market, Valuation adjustments

JEL classification: G12, G15, G18, G20, G28

*The views expressed in this paper are those of the authors, and are not necessarily those of the Bank of England. The authors would like to thank for constructive comments Sam Lagfield (referee), Thom Adcock, Evangelos Benos, Paolo Colla, Darrell Duffie, Mahmoud Fatouh, Peter Gee, Julia Giese, Mariam Harfush-Pardo, Russell Jackson, Lukas Kuenstl, David Macdonald, Darren Massey, Tim Meggs, David Murphy, Silvia Pezzini, Batchimeg Sambalaibat, Philip Strother, Marcel Sweys, Neeltje Van Horen, Haoxiang Zhu, and seminar participants at the Bank of England, European Central Bank, European Systemic Risk Board, Hebrew University of Jerusalem, Goethe University Frankfurt, Norwegian School of Economics, University of St Gallen, Stockholm Business School, and Tel Aviv University, as well as participants at the 2018 Western Finance Association meeting, the 2018 Annual Central Bank Workshop on the Microstructure of Financial Markets, the 2018 Bocconi-ESMA-CONSOB Conference on Securities Markets, the 2017 Federal Reserve Bank of Atlanta conference on 'Financial Regulation: Fit for the Future?', and the 2017 London School of Economics-Bank of England Financial Market Infrastructure Conference. Gino Cenedese and Angelo Ranaldo gratefully acknowledge financial support from the Canadian Derivatives Institute. Gino Cenedese started this project while being employed at the Bank of England.

[†]Fulcrum Asset Management, Marble Arch House, 66 Seymour Street, London W1H 5BT, United Kingdom. E-mail: gino.cenedese@fulcrumasset.com.

[‡]University of St Gallen and Swiss Finance Institute, Unterer Graben 21, CH-9000 St.Gallen, Switzerland. Tel. +41 (0)71 224 70 10. Facsimile: +41 (0)71 2247088. E-mail: angelo.ranaldo@unisg.ch. Corresponding author.

[§]Bank of England, Threadneedle Street, London EC2R 8AH, United Kingdom. E-mail: michalis.v@gmail.com.

1. Introduction

The Group of Twenty (G20) leaders agreed in 2009 on an ambitious agenda to reform and strengthen the financial system. At the centre of the agenda was the reform of over-the-counter (OTC) derivatives. What are the effects of the new regulation on derivatives pricing? Has it created stronger price heterogeneity? If so, how can we explain it?

To address these important questions, we provide the first empirical study of interest rate swaps (IRS) in the implementation of the new regulatory regime. Using unique and confidential data at transaction and identity (ID) levels, we find substantial and persistent heterogeneity in derivative prices. Besides the standard contract risk, IRS rates vary depending on whether the transaction is cleared via a central counterparty (CCP) or cleared bilaterally (non-CCP), if initial margin is posted, and on counterparty credit risk. These price differentials that we call *OTC premia* are highly significant in statistical and economic terms. We rationalise these OTC premia with increased inventory costs induced by the recent financial regulation that are passed on to market prices through so-called valuation adjustments (XVA). Also, OTC premia favour dealers in the sense that the extra cost in the non-CCP segment for interest rate protection (i.e., paying the fixed rate) is absent for dealers while it is large for clients suggesting pass-through of regulatory costs and bargaining power for dealers.

A better understanding of derivative markets is important for various entities including policy-makers and market participants. First, derivative markets are complex, opaque, and composed of many segments leading to price heterogeneity (Duffie, 2012). Indeed, there may be many sources of price heterogeneity, including different legal frameworks (e.g., different International Swaps and Derivatives Association (ISDA) agreements, accounting or regulatory rules), counterparty risk, types of agents (e.g., nonfinancial corporates versus dealers), and the overall difficulty to novate and negotiate across market segments. But at the same time, the sheer size of $544 trillion of notional value as of June 2016 (Bank for International Settlements, 2016a), the fact that derivatives are heavily traded by professional agents, and the new regulatory framework that has supposedly improved market quality in terms of transparency and (CCP) risk homogenisation should facilitate price efficiency. Thus, it is uncertain a priori whether the same derivative contract is more likely to be priced equally across different segments or types of market participants, in particular in the phase-in of regulatory reforms.

Second, in the wake of the recent global financial crisis policy-makers have implemented new regulations that have fundamentally changed the structure and mode of operation of OTC derivative markets. Among the declared objectives, there have been the increase of standardisation, central clearing, and the reduction of systemic risk, especially in terms of credit risk (Financial Stability Board, 2010). However, the new regulation may have created some unintended consequences such as the incentive of market participants bearing higher credit risk to circumvent clearing mandates by adjusting the terms of contracts to make them non-standardised (Financial Stability Board, 2017b). By analysing the transitional regime after the introduction of price-based measures such as Basel III capital charges but before the entry into force of the quantity-based European central clearing mandate in mid-2016, our work sheds light on whether these objectives have been achieved and it helps in deciphering future developments in OTC derivative markets. In fact, the implementation of these reforms is halfway through. More than half of the outstanding OTC derivatives, as measured by the number of contracts, are not yet centrally cleared (Financial Stability Board, 2017a), which reflects the fact that with the exception of plain vanilla interest rate derivatives and a limited number of credit default swaps (CDS) indices, most of OTC derivatives are not subject to any clearing mandate.[1] Since XVA applies to a range of products, such as FX derivatives (Andersen, Duffie, and Song, 2019), our study has external validity beyond the IRS market. Moreover, some categories of market participants such as pension funds and certain nonfinancial corporates are (still) exempt from central clearing and it is not clear how the new regulation will affect them.

[1] At the end of 2016, the share of global stock of outstanding OTC derivatives that was centrally cleared was 61% for interest rate derivatives, 28% for CDS, and minuscule for FX, commodity, and equity derivatives (Financial Stability Board, 2017a,b).

To introduce our pricing analysis, we map the USD-denominated IRS market that represents the largest segment of the entire interest rate derivatives market.[2] More specifically, we analyse every contract by non-US-based counterparties that traded with UK-based entities (including subsidiaries of foreign banks) and that was reported to the Depository Trust & Clearing Corporation (DTCC) between the beginning of December 2014 and the end of February 2016. The time span intentionally starts after the US clearing mandate (March 2013), but before the European one (June 2016). Throughout our sample period, US entities were required to centrally clear their transactions, and this is why we remove them, while the other counterparties in our sample (with access to CCP) had the choice whether to centrally clear their trades or not. This setting represents the ideal laboratory to study the distinguishing characteristics between the CCP and non-CCP segments, in terms of contract features, counterparty types, and how the trading activity in these segments evolves across time and risk. A unique feature of our data is the information on counterparties' identities, which allows us to analyse relevant issues such as the trader's credit risk and relationships.

To carry out the core analysis of our paper, we address the question whether there is substantial and persistent heterogeneity in derivative pricing in the phase-in period of the new regulatory regime and, if so, why. To do this, we analyse what explains IRS returns as conventionally defined, i.e., the difference between the transaction-level swap rate (i.e., the fixed leg of the swap contract) and the benchmark rate at the end of the previous day. More specifically, we perform panel regressions with day and counterparty fixed effects in which IRS returns are regressed on the main potential determinants of pricing heterogeneity as outlined by dealers' inventory and bargaining theories as well as XVA methods.

In line with inventory theories, market participants adjust derivative prices to inventory

[2]At end-June 2016, the notional outstanding for interest rate derivatives was $437 trillion (80% of the market), of which $327 trillion (60% of the market) were interest rate swaps, of which one-third was denominated in USD (Bank for International Settlements, 2016a).

holding costs of derivatives exposures.[3] In addition to hedging costs due to the contract exposure increasing with larger notional and longer maturities, dealers take into account costs originated from new regulations such as the Basel III capital and liquidity requirements. In this new regulatory framework, dealers will also require a compensation for holding derivative positions implying 'regulatory' costs. These effects will be different across types of agents and OTC segments generating price heterogeneity.

A further source of price heterogeneity is dealers' bargaining power that can arise from, e.g., the lack of outside options for customers (e.g., Duffie, Garleanu, and Pedersen, 2005, 2007), dealers' network centrality (e.g., Li and Schürhoff, 2019), financial expertise (e.g., Glode, Green, and Lowery, 2012), as well as information rents (e.g., Bolton, Santos, and Scheinkman, 2016). If dealers possess bargaining power against their customers (Duffie, 2012), then they will charge less favorable prices especially to entities with limited outside options.

Heterogeneous OTC premia are also fully consistent with the common valuation approach for derivatives that includes XVA elements such as Credit and Debit Valuation Adjustment (CVA, DVA), Funding Valuation Adjustment (FVA), Margin Valuation Adjustment (MVA), and Capital Valuation Adjustment (KVA). More specifically, from XVA pricing one can draw the following empirical predictions: first, the same IRS contract traded in the non-CCP segment rather than the CCP segment demands larger CVA and KVA resulting in a higher market price of the fixed leg for the buyer of interest rate protection. Second, when a customer pays fixed to a dealer in the non-CCP segment, the OTC premium decreases (increases) with the client's (dealer's) creditworthiness because a higher credit rating translates into a lower cost for buying protection (CVA) and lower capital charge (KVA). Third, the exchange of initial margin in non-CCP trades mitigates the effect of CVA and KVA (but increases the effect of MVA). Fourth, a higher contract

[3]Models of inventory effects are proposed in Stoll (1978), Amihud and Mendelson (1980), Ho and Stoll (1981), Mildenstein and Schleef (1983), O'Hara and Oldfield (1986), Grossman and Miller (1986), and Shen and Starr (2002). In particular, in Amihud and Mendelson (1980), O'Hara and Oldfield (1986), and Shen and Starr (2002) quotes and spreads depend on dealers' inventories. More recently, Pelizzon, Subrahmanyam, Tomio, and Uno (2016) extend the Stoll (1978) model to margins.

risk exposure in terms of notional and maturity implies higher XVAs for non-CCP rather than CCP contracts.

Some clear results emerge from our study. First, we uncover new stylised facts of the IRS market in the transition to the new regulatory regime, which are: (i) CCP trades are generally more standard contracts with larger notional and longer maturity;[4] (ii) the average market participant on CCPs is more likely to have higher creditworthiness consistent with the theoretical predictions that the non-CCP venue concentrates higher counterparty risk (Acharya and Bisin, 2014; Biais, Heider, and Hoerova, 2012, 2016);[5] and (iii) in distressed markets, market participants significantly increase their trading outside CCPs suggesting that they tend to circumvent the so-called margin procyclicality, i.e., tighter funding conditions and higher margins imposed by the CCP.

Second, we find substantial and persistent heterogeneity in OTC premia, which is significant in statistical and economic terms. For instance, when a client buys interest rate protection, she pays the dealer a fixed rate that is around 8 basis points higher for a non-CCP transaction relative to a CCP one. This is a sizeable amount considering the total traded notional of around 7.4 trillion US dollars over our sample period. The OTC premium reduces by at least half or even disappears if a non-CCP trade involves posting of initial margin. These results support the empirical predictions drawn from the XVA approach and point to credit risk (CVA) and capital charges (KVA) as important drivers of OTC premia for non-CCP transactions. Another important finding is that the OTC premium is not fully symmetric when dealers receive or pay the fixed rate to their clients, that is, OTC premia are significantly positive when dealers receive the fixed rate (consistent with dealers passing on XVA 'costs' to clients when selling interest rate protection) but neither systematically negative nor positive (i.e., there is neither a discount nor a premium) when dealers pay fixed. Our tentative explanation for the positive OTC premium when dealers

[4]'Standard' means that the contract maturity is 1Y, 2Y, 3Y, 4Y,..., 50Y or the last digit of the price (fixed rate) is 5 or 0.

[5]To the extent that low credit rating parties are also low volume players, this finding can also be the result of the high entry/usage costs of the CCP infrastructure.

receive fixed is bargaining or market power: dealers pass the XVA costs to their clients buying interest rate protection (i.e., paying fixed). Overall, these findings are consistent with the idea that (i) as with any inventory costs, dealers tend to pass on regulatory costs to market prices, and (ii) dealers exercise some bargaining power when they price swap contracts.

Third, we identify the main determinants of the OTC premia. In addition to the effect of initial margin described above, we find that swap prices tend to increase with notional amount and time to maturity, which capture contract risk. Moreover, the price a client bank pays (receives) for the fixed rate to (from) a dealer increases (decreases) with the bank's credit risk, which is again consistent with the pricing of CVA and KVA. Another finding is that there is no premium for transactions that are exempted from Basel III related capital charges, providing additional support for the effect of KVA.

Finally, we test whether alternative hypotheses, such as market liquidity, relationships, and bilateral exposures can explain our results. To do this, we exploit the execution of swaps on centralised electronic platforms, known as Swap Execution Facilities (SEFs), which increase transparency and dealer competition thus improving market liquidity (Benos, Payne, and Vasios, 2019). To examine bilateral relationships, we augment our regressions with buyer-seller fixed effects and time-varying bilateral relationships (e.g., time-varying dealer-client exposures). OTC premia remain statistically and economically significant.

We contribute to the empirical literature on derivative markets in several ways. First, although price dispersion due to over-the-counter frictions such as search costs and bargaining is well-grounded theoretically (e.g., Duffie et al., 2005, 2007), this is the first study providing empirical evidence that systematic OTC premia in IRS contracts exist. Our analysis also highlights the main determinants of OTC premia, namely, how the contract is cleared (CCP and non-CCP transactions), whether it involves margins, the types of market participants, and contract characteristics (notional and maturity).[6]

Second, our findings provide empirical support to the recent literature on the theory of XVA (e.g., Green, 2015; Gregory, 2015; Ruiz, 2015; and Andersen et al., 2019). In particular, Andersen et al. (2019) theorise the link between FVA and the dealer's price quotation to align the market-making function with shareholder interests. We provide empirical evidence that (i) overall, XVAs are priced in derivatives generating price heterogeneity and that (ii) CVA and KVA are important factors. Rather than a sign of inconsistency or frictions, our findings suggest that heterogeneity in derivatives prices results from an attempt to adjust efficiently valuations to specific contract characteristics and, arguably, to the new regulatory framework. On the other hand, we also find asymmetric patterns in the dealer-to-customer segment pointing to dealers' superior bargaining power even after controlling for other possible factors such as market liquidity and relationship issues.

Third, we contribute to the literature on central clearing, which has been studied mainly theoretically (e.g., Duffie and Zhu, 2011; Biais et al., 2012, 2016; Acharya and Bisin, 2014). The empirical literature devoted to CCP and OTC markets in post-crisis periods has mostly focused on CDS.[7] We contribute to this literature by providing empirical evidence that the CCP segment is relatively safer (in terms of credit risk), it supports standardisation and better prices (i.e., lower OTC premia), all of which are consistent with the policy objectives of promoting central clearing.

Finally, we provide empirical support to the growing literature on intermediary asset pricing (e.g., He and Krishnamurthy, 2013; Adrian, Etula, and Muir, 2014; He, Kelly, and

[6]Theoretically, price heterogeneity can arise from a number of reasons including search costs (e.g., Duffie et al., 2005, 2007; Lagos and Rocheteau, 2007, 2009; Atkeson, Eisfeldt, and Weill, 2015; and Afonso and Lagos, 2015) or informational issues (e.g., Duffie, Malamud, and Manso, 2009; Zhu, 2012; Babus and Kondor, 2018; Golosov, Lorenzoni, and Tsyvinski, 2014; and Babus and Hu, 2017). Empirical evidence of price dispersion in OTC markets is provided by, e.g., Jankowitsch, Nashikkar, and Subrahmanyam (2011); and Green, Hollifield, and Schürhoff (2007). More recently, Hau, Hoffmann, Langfield, and Timmer (2018) analyse dealers' discriminatory pricing in FX derivatives markets, while Cenedese, Della Corte, and Wang (2019) attribute currency mispricing to dealer balance sheet constraints.

[7]E.g., Arora, Gandhi, and Longstaff, 2012; Loon and Zhong, 2014, 2016; Duffie, Scheicher, and Vuillemey, 2015; Du, Gadgil, Gordy, and Vega, 2016; Bellia, Panzica, Pelizzon, and Peltonen, 2018). Another paper by Menkveld (2017) looks into CCP crowded risk in equity markets. By looking at IRS centralised trading, Benos et al. (2019) represent an exception focusing on the effects of the Dodd-Frank Act on market liquidity.

Manela, 2017) showing that financial intermediaries, in this case derivatives dealers, play a crucial role in the pricing of financial assets and in creating heterogeneity as well as asymmetry in derivatives prices.

The remainder of this paper is structured as follows. In Section 2 we provide an overview of the post-crisis derivatives regulatory framework. Section 3 describes the data. Section 4 contains the main empirical analysis, and Section 5 concludes.

2. Policy context

To reduce the risk and severity of future financial crises, global regulatory authorities around the world started a significant post-crisis programme of reforms. In regard to the OTC derivative markets, the main objective has been to incentivise centralised clearing, which was expected to reduce counterparty risk and simplify the network of bilateral exposures. We focus here on two of the reforms that are most relevant to this objective: the European Market Infrastructure Regulation (EMIR) and the Basel III framework.

In July 2012, the European Union issued EMIR, which lays down clearing requirements for OTC derivative contracts and uniform requirements for the performance of activities of CCPs.[8] The EMIR clearing obligation required eligible European counterparties to centrally clear certain types of OTC derivative contracts, including interest rate swaps. It was phased in from June 2016 on the basis of firms' categorisation and their trading volume in derivative contracts. Firms may fall in four different categories according to EMIR: (i) Category 1 comprises firms that are already clearing members of a CCP, and for which the clearing obligation took effect from 21 June 2016; (ii) firms in Category 2 are financial counterparties with a month-end average of outstanding notional amount of OTC derivatives above 8 billion euros, and were required to centrally clear from 21 December 2016; (iii) financial counterparties with an average notional outstanding below

[8]That is the Regulation (EU) No 648/2012 of the European Parliament and of the Council, of 4 July 2012 on OTC derivatives, central counterparties, and trade repositories.

8 billion euros fall in Category 3 and their initial clearing date was originally set to 21 June 2017, but subsequently postponed to 21 June 2019; (iv) finally, Category 4 includes all nonfinancial counterparties, whose initial clearing date was set to 21 December 2018. Note that intragroup transactions are exempt from central clearing; also, at the time of writing, pension funds benefit from a temporary clearing exemption under Article 89(2) of EMIR, and are likely to continue to benefit from this for some time (European Securities and Markets Authority (ESMA) statement ESMA70-156-641).

Central clearing requires market participants to comply with the CCP's risk management framework, which includes the exchange of initial and variation margin as well as the contribution to the default fund. EMIR also introduced risk-mitigation techniques for non-centrally cleared OTC derivative contracts. Under these uncleared margining rules phased in between January 2017 and September 2020, all covered entities (i.e., financial firms and systemically important nonfinancial entities), are required to exchange variation margin and initial margin on a regular basis for non-CCP trades.

The Basel III framework was announced in 2010 and developed by the Basel Committee on Banking Supervision (BCBS). It consists of a comprehensive set of regulations affecting every aspect of banking, from capital to liquidity and resolution. This framework is structured in several phases, with the first phase starting in 2013, while it has been reviewed a few times, most recently in 2017. The leverage ratio (i.e., the ratio of Tier 1 capital to total exposures) and the risk-weighted capital requirements (i.e., the ratio of capital to risk-weighted assets) are at the core of Basel III. The minimum internationally agreed Tier-1 capital requirement is 6% of risk-weighted assets, but there are typically additional buffers set to absorb losses under stress. With respect to the leverage ratio, the BCBS required banks to publicly disclose their leverage ratio from January 2015, and proposed a minimum ratio of 3% that was scheduled to become binding in January 2018.

While the scope of Basel III is broad, it has far-reaching implications for the operation of OTC derivative markets. For example, in July 2012, the BCBS, in consultation with the Committee on Payments and Settlement Systems (CPSS) and the International

Organization of Securities Commission (IOSCO), assigned a small risk weight of 2% for bank exposures to central counterparties. The BCBS also introduced a cap on the capital charge on banks' exposures to CCPs in April 2014. These policies aimed to promote central clearing.

The treatment of counterparty credit risk in Basel III has also impacted the trading of OTC derivatives. Basel II had addressed this risk using the default capital charge, intended to cover any losses due to a counterparty's default. However, the global financial crisis showed that two-thirds of counterparty-risk-related losses were due to the movement of the credit quality of counterparties, rather than actual defaults (Basel Committee on Banking Supervision, 2009).[9] To address this gap, Basel III introduced (in December 2010) the CVA capital charge as a protection against mark-to-market losses caused by an increase in the credit spread of the counterparty. More importantly, exposures to CCPs were exempted from the CVA capital charge, which otherwise would have been a significant cost of trading in the CCP segment.

Counterparty capital charges differentiate between margined and unmargined non-CCP transactions too. This is because initial margin reduces the amount of exposure for OTC derivatives transactions. For example, the standardised approach for measuring counterparty credit risk exposures (SA-CCR), introduced by the BCBS in April 2014, allows for a reduction in the exposure at default (EAD) when initial margin is received by the counterparty, through a reduction in EAD's two main components: the replacement cost (RC) and the potential future exposure (PFE). With respect to the leverage ratio, its calculation does not recognise collateral or other credit risk mitigants as an offset to derivatives exposures. This is fundamentally different from the risk-weighted framework, which favours the exchange of initial margin in centrally or bilaterally cleared transactions.

[9] The UK Financial Service Authority estimated that losses of UK banks during 2007–2009 related to the market risk nature of counterparty risk were five times the amount of actual default losses. See http://www.fsa.gov.uk/pubs/discussion/dp10_04.pdf.

2.1. *An illustrative example of XVA*

The new regulatory landscape is changing the pricing of OTC derivatives. Market participants move away from textbook-type pricing formulas and start to take into account the underlying credit, collateral, funding, and capital implications of every transaction. It is common for banks to actively manage these components and to incorporate them into prices through valuation adjustments, a practice known as XVA. For example, the CVA is the adjustment taken upfront against counterparty defaults. The KVA takes into account costs related to capital requirements (default capital charge and the CVA capital charge). The MVA incorporates the cost of posting initial margin. Finally, the FVA reflects the cost of funding liquidity.

The following example illustrates how new regulation generates (heterogeneous) impacts on swap prices via the XVA. Let's assume that a dealer-bank sells interest rate protection to a client via a 10-year IRS contract with a theoretical fixed rate of 1%. This fixed rate ensures that the fixed and floating leg of the swap have the same present value. Assuming there are no pre-existing positions between the dealer and the client, and no interdealer hedge, the following valuation adjustments apply:

- If the swap is centrally cleared, it will put pressure on dealer's funding liquidity (FVA, MVA) because of the need to manage the posting of margin, on the one hand, while it will introduce a small capital charge (KVA) because of the 2% risk weight for bank exposures to central counterparties, on the other hand. Given the low counterparty risk associated with CCP trades, there will be no CVA or CVA capital adjustment. In theory, there could be a CVA adjustment to reflect the mutualisation of counterparty risk via the default fund, but in practice this is not generally considered important.

- If the swap is bilateral and uncollateralised, it will introduce costs related to counterparty risk (CVA) and capital (KVA) as a result of the associated cost for hedging the counterparty credit risk, the default capital charge, and the CVA capital charge. The magnitude of these costs will be negatively correlated to the creditworthiness of the client. This is because both the cost of buying protection against counterparty default (default probability $\uparrow \Rightarrow$ CVA $\uparrow$) and the credit spread volatility (CVA capital charge $\uparrow \Rightarrow$ KVA $\uparrow$) increase for low-credit-rating counterparties.[10]

- The exchange of initial margin in the bilateral case will reduce the counterparty risk (loss given default $\downarrow \Rightarrow$ CVA $\downarrow$) and capital (exposure at default$\downarrow \Rightarrow$ KVA $\downarrow$) costs, but it will increase other costs related to collateral and funding management (MVA). It is unclear how the MVA adjustment for a bilateral trade with initial margin should compare to the MVA adjustment for a CCP trade. Note that our sample period is before the implementation of the uncleared margining rules and as a result counterparties calculate initial margin using their internal (non-standardised) models (Gregory, 2015).[11] On the one hand, CCP risk models calculate initial margin using a 5-day close out period against typically a longer period for bilateral trades and offer more netting opportunities (multilateral netting), which suggests a smaller initial margin for CCP trades ($\text{MVA}^{CCP} \downarrow$). On the other hand, a CCP's initial margin tends to be more risk-sensitive and is collected daily, whereas a bilateral initial margin is less procyclical and collected less frequently ($\text{MVA}^{CCP} \uparrow$). Bilateral initial margin can also be linked to thresholds and minimum transfers, leading to undercollateralisation ($\text{CVA}^{Non-CCP} > \text{CVA}^{CCP}$).[12]

Overall, each of these adjustments will push the fixed rate higher than the 1% theoretical price in order to compensate the dealer, who is the receiver of the fixed rate, for incurring the additional costs.

[10] For example, Hull, Predescu, and White (2005) show in a simplified example that the real-world default probability of a Baa bank is ten times larger than that of a Aaa bank.

[11] After the implementation of the uncleared margining rules (phased in in Europe between January 2017 and September 2020), the covered entities who trade in the non-CCP segment would be required to exchange variation margin regularly (e.g., daily) and initial margin over a 10-day time horizon with more stringent threshold and minimum transfer rules. This will likely increase the MVA for bilateral trades ($\text{MVA}^{Non-CCP} \uparrow$) and further reduce their CVA and KVA.

[12] The threshold is the amount below which collateral is not required. A minimum transfer is the smallest amount of collateral that can be transferred. See Chapter 6 in Gregory (2015) for more details.

3. Data

We use transactions of USD-denominated spot fixed-to-floating IRS contracts executed between 1 December 2014 and 21 February 2016. We focus on the USD-denominated segment of the market because this is the largest and most liquid segment in terms of turnover (Bank for International Settlements, 2016b). The source is the DTCC, the largest European trade repository (TR).[13]

The time span intentionally starts after the US clearing mandate (March 2013), but before the European one (June 2016). This means that while US entities were required to centrally clear their transactions (and this is why we remove them), the other counterparties in our sample (with access to CCP) had the choice whether to centrally clear their trades or not. The start date in December 2014 is chosen for data quality reasons. Before December 2014, many values were missing in key variables in the DTCC data until a process of validation was introduced by the European Securities and Markets Authority (ESMA), after which the data quality dramatically improved, as shown in Cielinska, Joseph, Shreyas, Tanner, and Vasios (2017) and Abad et al. (2016). In addition, note that although the European clearing mandate came into force in June 2016, EU counterparties had to centrally clear all transactions with a remaining maturity of more than six months from 21 February 2016 onwards, as a result of the EMIR frontloading requirement. Hence, we use 21 February 2016 as the cut-off date.

The DTCC data provide information on flows, for example, new trades, modifications, valuation, and cancelation updates.[14] Each transaction report contains more than 100 fields that include information on trade characteristics (e.g., price, notional amount, maturity

[13] Abad, Aldasoro, Aymanns, D'Errico, Rousova, Hoffmann, Langfield, Neychev, and Roukny (2016) report that the European DTCC data cover about 70% of the global interest rate swap market.

[14] Under EMIR the Bank of England is entitled to see (i) trades cleared by a CCP supervised by the Bank and trades in which one of the counterparties is a UK entity. The definition of entities includes CCPs; financial counterparties, such as banks, insurance firms, and hedge funds; and nonfinancial counterparties that are EU legal entities, but exempts some other entities, for example, EU national central banks and natural persons. See Article 2 of Commission Delegated Regulation (EU) No 151/2013 - Data access by relevant authorities.

date, execution time, reference rate), whether a trade is centrally cleared and the type of the collateral exchanged, and, more importantly, counterparty identities.[15] This allows us to categorize trades by type of counterparty and location.

We carefully apply a number of filters to clean the data. We start by keeping only USD-denominated spot-starting swaps, which we do by removing any reports whose effective date is more than two business days from the trade date. Next we remove duplicate reports. Duplication is mainly due to three reasons. First, EMIR is a double-sided reporting regime, so we see two copies for a single trade when both counterparties are UK legal entities and both of them report to DTCC. Second, as per the EMIR regulation, the data contain several copies of the same trade to reflect any modification, correction, and valuation updates. We remove these duplicates using the unique trade identifier (UTI) of every report.

Another reason for duplication is that for every transaction that is centrally cleared there are typically three reports sent to the TR: the original transaction (alpha trade report) and the two novations (beta and gamma trade reports). These reports tend to have different UTIs. We remove these duplicate reports by applying an algorithm that matches trades based on trade date and time, effective date, maturity date, notional, swap rate, and counterparty identities. In addition, for every trade that is cleared by the London Clearing House (LCH), which has more than 90% market share in the cleared interest rate swap market, we obtained the trade identifiers of the associated (two) novations directly from LCH. We accurately remove these duplicate novations by using the LCH information in conjunction with the matching algorithm.

Finally, to remove any false or inaccurate reports we only keep trades with a fixed rate that is within 150 basis points from the benchmark (same maturity and currency) end-of-

[15]For bilateral trades, DTCC data provide information on whether the transaction is uncollateralised (i.e., no exchange of variation or initial margin), partially collateralised (i.e., exchange of variation margin), or fully collateralised (i.e., exchange of variation and initial margin).

day swap rate mid-quote from Bloomberg.[16] The Bloomberg benchmark is the rate used by practitioners to proxy the 'fair' value of the prevailing fixed rate. After filtering the data we are left with 169,996 reports out of which 68,945 involve US persons, who were subject to the US clearing mandate and as a result, they had no choice but to centrally clear their trades.[17] After excluding these reports from our analysis, the final sample consists of 101,051 new trades by about 800 active counterparties, which account for a total of $\$7,470$ billion in traded notional over our sample period.

Fig. 1 shows the daily time series of traded notional by segment. The CCP segment includes all trades cleared by a clearing house.[18] The non-CCP segment consists of all non-cleared or bilaterally cleared reports. Fig. 1 illustrates the immense size of the IRS market with the daily notional traded hovering around $15–30 billion, of which about 10% takes place in the non-CCP segment across the whole sample period. To get a sense of the data coverage, we compare them against the data from the global CCP USD IRS market used in Benos et al. (2019). They report a daily notional traded by non-US counterparties of about $20 billion between 2013 and 2014, which indicates that we see the lion's share of the (non-US counterparty) global USD IRS market, a result of London's status as a global centre for derivatives trading.

[16] This is necessary as some counterparties mistakenly report the swap rate in basis points instead of percentage points. Our filter ensures the removal of these inaccurate (about 4,800) reports. As robustness analyses, we experimented with other filter methods. For example, (i) we trimmed swap rate log-returns, defined as the log-difference between the transaction-level swap rate and the benchmark end-of-day swap rate mid-quote from Bloomberg, at the 2.5% and 97.5% levels; or (ii) we trimmed swap rate absolute returns, defined as the difference between the transaction-level swap rate and the benchmark end-of-day swap rate mid-quote from Bloomberg, at the 2.5% and 97.5% levels, among others. Our results are not sensitive to the filtering approach and remain qualitatively the same.

[17] Note that in Japan counterparties are required to centrally clear only those IRS contracts that are denominated in JPY, which are not included in our study as we focus on USD-denominated contracts. Also, other jurisdictions introduced a clearing mandate only after the time period spanned by our sample; for example, Singapore introduced the mandate in October 2018. The largest group in our data is UK counterparties, who account for 57% of total traded notional, followed by French and German counterparties with 12% and 9% of market share, respectively. See Table A.1 in the Internet Appendix.

[18] The DTCC data contain a flag that equals one for centrally cleared trades and zero otherwise. However, we observe that some reports with a zero value involve a clearing house as a counterparty (LCH or the Chicago Mercantile Exchange). We classify these cases as centrally cleared. Finally, we require that clearing takes place on the execution date (T+0), which follows the definition of ESMA. By extending the cut-off time up to five days, we obtain a slightly larger non-CCP subsample and the results remain unchanged.

4. Empirical Analysis

4.1. Descriptive statistics

Before conducting any in-depth analysis of OTC premia we present some key insights into the USD IRS market that we summarise in Table 1. We start with the breakdown of the market by segment and counterparty type. The daily notional traded (by non-US investors) of around \$15 billion reiterates that the USD IRS market is economically very important, as depicted in Fig. 1. The CCP segment dominates trading with a market share of 85% and 90% in terms of number of trades and notional, respectively. Although a fraction of the total market, the non-CCP segment remains an economically significant quantity with daily notional of about \$1–2 billion and in number of trades terms, about one out of six trades is non-centrally cleared.

The availability of counterparty IDs allows us to classify entities into meaningful groups: dealers, banks, hedge funds, asset managers, insurance companies and pension funds, other financial companies, and nonfinancial companies.[19] There are also some entities that could not be classified, mainly because of missing ID information. Their trades are typically small, infrequent, and non-centrally cleared. Collectively they account for 8% of trades.

In Table 1 (Panel B) we present trading activity variables by type of counterparty throughout our sample period. G16 dealer trading accounts for about two-thirds of trading in terms of both notional traded and number of trades. The rest of trading is split between banks (13% of notional), hedge funds (7.8%), asset managers (1.2%), and others. It is worth noting that although smaller non-bank players such as insurance companies, as well as other financial and nonfinancial companies trade rather infrequently, their trading collectively sums to the economically significant amount of \$205 billion over the whole

[19] The 'dealers' category includes the so-called 'G16' dealer-banks: Bank of America, Barclays, BNP Paribas, Citibank, Credit Agricole, Credit Suisse, Deutsche Bank, Goldman Sachs, HSBC, JP Morgan, Morgan Stanley, Nomura, Royal Bank of Scotland, Societe Generale, UBS, and Wells Fargo. This choice is not arbitrary on our part as these banks are also classified as "Participating Dealers" in the OTC Derivatives Supervisors Group, chaired by the New York Fed https://www.newyorkfed.org/markets/otc_derivatives_supervisors_group.html.

sample, or $630 million per day.

We next report descriptive statistics at the trade level and across market segments in Table 2. The average notional of CCP transactions is $79 million, which is about 80% larger than that of the typical non-CCP transaction, which averages to $45 million and $40 million for collateralised and uncollateralised transactions, respectively. The distribution of the notional traded is rather dispersed though, with a standard deviation of more than $120 million in all segments. Interest rate swaps are long-lived. CCP contracts have an average maturity of ten years, which is more than one year longer than that of non-centrally cleared swaps. We observe some bunching around 5- and 10-year maturities in all segments.

Table 2 also displays the statistics of the average swap rate return per trade. Note that this return is calculated against the end-of-day swap rate mid-quote from Bloomberg from the previous business day (to avoid any endogeneity concerns), which is publicly available to every market participant at the start of the trading session.[20] The average swap rate return is positive, consistent with the upward Overnight Index Swap (OIS) term structure and with the upward interest risk prevailing during our sample period. Interestingly, the average returns are 1.78, 2.19, 2.52 basis points (bps) for CCP, non-CCP collateralised (with exchange of variation margin and/or initial margin), and non-CCP uncollateralised trades, respectively. This increasing order suggests that the cost for interest rate protection (i.e., paying fixed) is most (least) expensive in the non-CCP (CCP) segment, especially if uncollateralised. We investigate the determinants of these price differentials in Section 4.3.

Finally, Table 2 reports the average credit rating of the buyer (paying fixed) and the seller (receiving fixed) of a swap contract. We use the credit ratings to proxy for counterparty credit risk, which affects investors' trading decisions (with whom to trade and where) and has implications for the pricing of swaps, for example, via the CVA channel. Because these ratings are typically available at the quarterly frequency, we match the buyer

[20]We replicated our regression analyses by computing returns using the same end-of-day swap rate mid-quote from Bloomberg and we find similar results in terms of OTC premia.

and seller of a swap with their credit ratings in the previous quarter.[21] So, if a swap was executed on 10-Feb-2015, we use the ratings (when available) of the two counterparties in Q4 2014. We take the ratings from three different sources (Standard & Poor's (S&P), Moody's, and Fitch) and average them after first converting them to a scale from zero to 20, where zero denotes the worst rating and 20 the maximum rating (see Table A.2 in the Internet Appendix for the conversion of each rating). Table 2 shows that credit ratings are available only for a subset of counterparties, and largely for dealers and banks. The average rating is about 14, which corresponds to a rating of A- for S&P and Fitch, and A3 for Moody's. The average rating varies from 14.49 to 14.94 for buyers and 13.72 to 14.73 for sellers across market segments, and the standard deviation corresponds to more than one 'notch' (a unit in our scale of ratings corresponds to about one notch).

4.2. Trading across OTC segments

The summary statistics hinted at some distinctive characteristics of derivatives traded in the different OTC segments. Next we explore these patterns more formally using a probit regression approach. More specifically, we examine whether the likelihood to trade in the CCP or the non-CCP segment increases with some contract characteristics, counterparty type, and counterparty credit risk. Note that in our data counterparties (CCP members and those who have access to client clearing services) have the option to choose where to trade throughout the sample period, because even if they are clearing members, they are not subject to any central clearing obligation.

We start with investigating the role of contract characteristics. We present the first set of results in Table 3, where the dependent variable is one for non-centrally cleared trades and zero otherwise. The first variables of interest, the log-notional and the maturity, both have a negative sign in specification 1. This result shows that trades with larger notional and longer maturity are in relative terms more likely to be centrally cleared. We next look

[21] As an alternative measure of credit risk, we used the credit default swaps and default probability estimates from Kamakura Corporation. The main advantage of these two credit risk proxies is the daily frequency. However, they cover a smaller subset of entities for which we obtain similar results.

at the role of contract standardisation. The basic idea is that bilateral (or no) clearing might be best suited to more bespoke contracts. We define two types of standardisation with respect to maturity and price. A transaction is considered 'standardised' when its maturity is 1Y, 2Y, 3Y, 4Y,. . . , 50Y or when the last digit of the price (fixed rate) is 5 or 0. For example, a 5Y swap with 1.05 fixed rate has a standardised maturity and price. Specification 2 shows that contract standardisation is associated with more central clearing. The results remain qualitatively the same when all four variables are included in the same regression (specification 3). If we translate the findings of specification 3 into probability terms, then they suggest that a one-unit change in (log) notional or maturity increases the probability of a CCP trade by 6% and 0.6%, respectively.[22] Similarly, having a standardised maturity or price, increases the probability of a CCP trade by 5.6% and 1.9%, respectively. However, most of the explanatory power (i.e., R^2) comes from the notional and maturity, and it is for this reason that we use only these variables as controls in the following probit regressions.

We next examine the role of counterparty characteristics. As seen already in the descriptive statistics in Table 1, dealers and other banks rely more on the CCP segment, while small financial and nonfinancial companies tend to use more often the non-CCP segment. Specifications 1 and 2 in Table 4 make this point more formally. As before, the dependent variable in the probit regressions is one for non-centrally cleared trades and zero otherwise. On one end of the spectrum, the more active counterparties tend to centrally clear their transactions, as indicated by the negative coefficients of dealer, bank, and hedge-fund dummy variables. On the other end, nonfinancial or less active counterparties have positive coefficients indicating that they are more disposed to non-CCP clearing.

Counterparties can also differ with respect to how and at which cost they access the CCP infrastructure. CCPs can be accessed either directly via house accounts for clearing members (CM) or indirectly via client accounts by using the clearing services offered by

[22]We calculate this probability as the sample average of the marginal effect of changes in a regressor on the conditional probability that a trade is centrally cleared (e.g., Cameron and Trivedi, 2010).

CMs. To investigate whether direct or indirect access to CCPs matter for our results, we construct two dummy variables that use information on house and client accounts that we obtained directly from LCH, together with information on the list of clearing members, which we obtained from the website of the Chicago Mercantile Exchange. The first variable is denoted as 'CCP client,' which equals one when a counterparty clears via a client account, and zero otherwise; the second variable is denoted as 'CM/CCP client,' which equals one if the counterparty is either a clearing member or has a client account with a CCP and zero otherwise. Not surprisingly, the results from specifications 3 and 4 in Table 4 suggest that counterparties with indirect access to CCPs are in relative terms less likely to centrally clear their transactions, as shown by the positive coefficient of the 'CCP client' variable. In economic terms, the results in specification 4 suggest that having an established access to a CCP, which is captured by the 'CM/CCP client,' increases the probability of central clearing by 23%, whereas having only indirect access reduces this effect by 3%. This is perhaps a result of the higher CCP usage costs (e.g., fees for using the service) for investors with client accounts, who in addition do not benefit from multilateral netting.[23]

Another counterparty classification is with respect to their position in the trading network. At the core of the network are the big dealers who speed up the search for counterparties by intermediating in the dealer-to-client (D2C) market, while they rebalance their inventories in the interdealer (D2D) market. The IRS interdealer market is traditionally considered a centrally cleared one, with LCH having a predominant role. Specifications 5 and 6 in Table 4 confirm the anecdotal evidence as they suggest that trading in the D2C market reduces the probability of central clearing by 21% (specification 6).

Finally, we look at the role of counterparty credit risk at the investor and market levels. In a similar probit regression setting as before, we first look at the association between central clearing and investors' credit ratings, which we use to proxy counterparty-specific

[23]The treatment of the initial margin posted by client accounts in the leverage ratio of the CMs that offer this service is another consideration, as it increases the cost of offering clearing services, making client clearing more expensive. This cost might become more material after the implementation of the clearing mandate and the subsequent increase in demand for client clearing services (given also the high concentration in the provision of client clearing).

credit risk. Table 5 reports the results of these regressions for the counterparties for which credit rating information was available.[24] Overall, specification 1 shows that higher credit quality goes hand in hand with higher likelihood of centrally cleared trades. One explanation could be the amount of margin or funding cost for margin, as they are both higher for less creditworthy counterparties. It should be noted that among these counterparties there are only few *without* access to the CCP (clearing members or clients). More precisely, they account for only about 0.9% (0.3%) in terms of number of trades (notional). Therefore, our results are more likely to arise from (endogenous) counterparty choice rather than some institutional rigidities (e.g., denied access to central clearing services for non-investment-grade firms).[25] Indeed, if we exclude from the regression the counterparties that do not have access to central clearing services, the results are qualitatively the same (see Table A.3 in the Internet Appendix).

However, different categories of credit rating may have different effects. For instance, the non-investment-grade prevents market participants from accessing central clearing services thereby inducing nonlinear patterns or opposite effects for investment-grade companies. To test this conjecture, we augment the model with various sets of dummy variables that equal one for different buckets of credit ratings. In the regression specifications 2 to 4 reported in Table 5, the dummy variables are organised in three ranges of credit ratings: below 11 (that is, "non-investment-grade"), from 11 to less than 15 ("medium grade"), and above 15 ("high grade"). These three buckets include about 0.2%, 48.8%, and 51.2% of the total number of transactions (0.1%, 49%, and 50.9% of notional), respectively. The results show that transactions with non-investment-grade counterparties have a higher likelihood (16% more) of being cleared bilaterally than the average transaction. In contrast, medium-grade counterparties have only a 1% more probability to clear bilaterally while high-grade counterparties are more likely to centrally clear their trades.

[24] Note that credit rating information is mainly available for dealers and banks, which explains the drop in the number of observations when we include them in the regressions. These entities trade frequently and have well-established CCP relationships (via home or client accounts).

[25] Survey data show that some clients face difficulties in establishing an account with a provider of central clearing services; see Financial Stability Board (2018).

Another important issue is whether the decision to centrally clear or not changes in times of stress. Although the CCP segment is predominant under normal market conditions, there can be an increase in trading outside CCPs as a consequence of the elevated cost of margin in periods of stress, known as margin procyclicality. To shed light on this issue, we augment the probit regression with two proxy variables usually associated with market stress: the VIX index of volatility implied by S&P 500 index options, which is typically used as a measure of global risk perceptions; and the spread between the three-month London Inter-bank Offered Rate (Libor) and the Overnight Index Swap rate, which is often used as an indicator of funding strains in the interbank market. Specifications 5 and 6 of Table 5 indeed suggest that higher readings of these variables tend to be associated with a higher likelihood of bilateral clearing. One possible explanation is that procyclicality causes funding liquidity pressure to parties that need to find liquid and eligible assets to post as margin, at times when it is most difficult for them to do so (see Brunnermeier and Pedersen, 2008; Murphy, Vasios, and Vause, 2014). To the extent that credit risk and funding risk are interrelated, this explanation is consistent with the previous result indicating that non-investment-grade counterparties tend to clear more bilaterally. Overall, our results support the view that market participants might circumvent CCPs' stricter margining practices and adverse effects such as funding liquidity stress by clearing bilaterally.

4.3. Determinants of OTC premia

We now turn to the pricing of IRSs across the different OTC segments. An IRS is a plain vanilla swap contract that consists of a fixed leg whose payments depend on a fixed rate and a floating leg whose payments depend on a floating rate (the Libor). It is used by traders to remove interest rate risk from their trading book. The seller of the swap, i.e., the *receiver of fixed*, is selling protection against interest rate risk and would bear a loss in case of upward interest rate movements. Therefore, the market value of the contract, which is typically zero at initiation, is driven by changes in interest rates (the term structure), which is the main risk factor. In line with the literature on dealers' inventory effects (e.g., Amihud and Mendelson, 1980) and bargaining power (e.g., Duffie, 2012), dealers are incentivised to pass any regulatory and XVA-related costs to clients. To test this, we focus on transactions between dealers and clients, that is, excluding the interdealer segment.

Given the OTC nature of trading in swap markets, there is little information about the fair value of a swap before the trade. The market convention is to use an industry benchmark, provided by financial data vendors like Bloomberg, as a proxy for the 'fair' value of the prevailing fixed rate. In line with this practice, we use Bloomberg end-of-day information to construct the '*swap return*,' formally defined as the difference between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day.[26] Intuitively, the swap return captures the price divergence from the swap rate's fair value.

To analyse the determinants of swap returns, we run panel regressions of the form

$$R_{k,i,j,t} = \beta \mathit{Non\text{-}CCP} + \gamma' X_{k,i,j,t} + \delta_i + \zeta_j + \theta_t + \epsilon_{k,i,j,t}, \tag{1}$$

where $R_{k,i,j,t}$ is the swap return for transaction k between counterparties i and j on day t; 'Non-CCP' is a dummy variable that is equal to one for any transaction that is not centrally cleared (either client cleared or directly cleared by a CCP) and zero otherwise; $X_{k,i,j,t}$ is a vector of transaction-level contract and counterparty characteristics; and δ_i, ζ_j, and θ_t denote fixed effects. $X_{k,i,j,t}$ includes the logarithm of the trade size ('Log-notional'), the contract's maturity ('Maturity'), and the credit ratings of the counterparties. In some

[26]The Bloomberg end-of-day rates are composite measures of indicative quotes from a selected number of 'contributors' (dealers), and as such they reflect the daily market average 'risk-neutral' prices. One may wonder whether non-CCP transactions tend to take place systematically before or after the centrally cleared ones, and therefore bias our results. We report the empirical distributions, grouped in hourly baskets, of the two different types of transactions in Fig. A.1 in the Internet Appendix. Visual inspection of the empirical distributions shows that there is no noticeable difference in the two distributions. We also control more formally for this potential issue by running a robustness exercise by using hour fixed effects absorbing intraday patterns. The results, which we report in Table A.4 in the Internet Appendix, show that our results are robust.

specifications, we control for additional dealer characteristics, that is, the capital ratio ('CR') and leverage ratio ('LR').[27] In all results here and below we report robust standard errors clustered at the quarter and dealer levels, unless otherwise stated.

Our main interest lies on the coefficient β of Eq. (1), which should capture the *OTC premium* by measuring the difference in the price (fixed rate) between CCP and non-CCP swaps after controlling for time, counterparty, and contract characteristics. If β is positive then a swap executed in the non-CCP segment will be costlier than an equivalent contract that is centrally cleared, in the sense that the buyer of the swap will have to pay a higher fixed rate.

Table 6 shows the main results of IRS return determinants when the dealer receives fixed (that is, sells interest rate protection to the client) and when the dealer pays fixed (that is, buys protection from the client). We discuss first the results for the former case reported in Columns 1 to 4. This analysis provides evidence for the existence of the OTC premium. That is, the swap return for non-CCP transactions is about 8 basis points larger than that of centrally cleared transactions, controlling for other variables. Besides being strongly statistically significant, this OTC premium is also economically significant: given the average fixed rate in our sample period of about 1.82%, the β coefficient suggests that the fixed rate of non-CCP swaps is on average 4% higher than that of equivalent CCP swaps. Columns 5 to 8 deliver a second important result, that is, when the dealer pays fixed the premium is smaller and not statistically significantly different from zero. In case of maximum dealers' bargaining power, we could have expected negative OTC premia if dealers paying the fixed fully reverse XVA charges to customers. This asymmetric pattern can arise when the interest rate risk is mainly on the upper side, as it was during our sample period. In such a market environment, the payer of fixed (including dealers) is willing to pay a premium to protect herself against the interest rate risk while the receiver

[27] Note that the credit rating information is mainly but not only available for banks. This is why there is a reduction of number of observations in Table 6 and Table 8 relative to the previous tables. In addition, the capital and leverage ratios are only available for a subset of dealers, and it is for this reason that in Table 6, Table 7, and Table 8, Columns 2, 4, 6 and 8, there is a further reduction of the number of observations.

of fixed is likely to have an advantage at setting prices, in which case perhaps also making harder the identification of the XVA effects.

According to the empirical prediction discussed in Section 2.1, the OTC premium should be lower when initial margin is posted. We test this hypothesis using variations of the following empirical model:

$$R_{k,i,j,t} = \beta_1 \textit{Non-CCP} + \beta_2 \textit{Non-CCP with IM} + \gamma' X_{k,i,j,t} + \delta_i + \zeta_j + \theta_t + \epsilon_{k,i,j,t}. \quad (2)$$

This model includes a dummy variable ('Non-CCP with IM') that equals one when initial margin is exchanged (i.e., full collateralisation), and zero otherwise. Columns 3 and 4 in Table 6 show that the exchange of initial margin in the non-CCP segment reduces the swap return by about 4 to 9 basis points. This result points to the pricing of the counterparty credit risk in non-centrally cleared swaps, which is in line with the CVA and KVA valuation adjustments. These findings support the empirical predictions discussed in Section 2.1: the posting of initial margin reduces (i) the loss given default and (ii) the exposure at default, which reduce the cost to buy protection against counterparty default and Basel III capital charges. The same result also suggests that the funding cost associated with the posting of initial margin (MVA) is smaller compared to the CVA and KVA, at least during our sample period.[28] Another observation is that margin does not play a significant role when dealers pay fixed (buy protection).

In the results so far, we included both non-dealer banks and non-banks in the clients category. Next, we split clients into banks and non-banks, as different XVA effects can arise from the latter group. Table 7 reports the results of the analogous regressions described above, but where the sample includes only transactions in which the client is a non-bank.

[28] The move to a higher interest rate environment and the forthcoming implementation of the more stringent uncleared margining rules are likely to increase the future impact of the MVA.

In these regressions the sample size increases, because we have dropped the client-specific controls (i.e., credit rating, capital ratio, and leverage ratio) as they are only available for banks. We continue to control for dealer specific variables and client and dealer time-invariant characteristics.

The results reported in Table 7 are consistent with the previous findings. When dealers receive the fixed rate, we still find a positive and significant OTC premium corroborating the bargaining power hypothesis. As discernible in Columns 1 to 4, the coefficient of the 'Non-CCP dummy' is smaller in magnitude than that reported in Table 6 for three possible reasons: first, the sample of market participants is different; second, different XVAs can arise from non-banks; third, the non-bank subsample includes firms exempted from Basel III capital charges, leading to a smaller KVA. We elaborate upon the latter in the next section. Interestingly, Columns 5 to 8 show a negative coefficient for the 'Non-CCP dummy' when dealers pay the fixed rate, although statistically significant only in Column 6. This reinforces the idea that dealers exercise their bargaining power and pass on their costs to non-bank clients. That is, dealers tend to fully charge XVA costs that translate into a positive (negative) OTC premium when they receive (pay) fixed. When they pay fixed, the discount is about 3 basis point in specification 6, where we control for all dealer characteristics. In line with the pricing of CVA and KVA, when the dealer receives the fixed and the initial margin is posted, the OTC premium drops by about 2 basis points. The IM results are less significant (the p-value is only 12% in Column 3) for non-banks, which is not surprising given that non-banks tend to post margin less frequently (for example, they are linked to thresholds and minimum transfers), resulting in a smaller reduction in CVA and KVA. When dealers pay fixed the role of margin is not significant.

The results in Tables 6 and 7 are robust to the exclusion of entities with unclassified location, which constitute about 3% of notional traded in our sample. When we perform the main regressions excluding these entities, we obtain very similar results. More specifically, the results in Table 6 are actually unchanged, and the reason is that the counterparties without location do not have credit ratings and therefore these entities were never included in the regressions. The results for non-banks are slightly affected (see Table A.5 in the Internet Appendix), but they remain quantitatively similar. In fact, the premium when dealers sell protection (receive the fixed) is significant and positive, as before. However, when dealers pay the fixed rate the premium is not statistically significant (while it is slightly statically significant in Table 7, Column 6). All things considered, the main conclusions remain essentially unchanged.

Table 8 digs deeper into the determinants of the OTC premium. We interact the non-CCP dummy variable with the possible determinants in terms of contract and counterparty characteristics. The coefficients on the interaction terms indicate the effect of notional, maturity, and buyer/seller credit rating conditional on the contract being transacted on the non-CCP segment. These contract and counterparty characteristics appear to explain most of the OTC premium as the coefficient of the non-CCP dummy variable in all specifications becomes not statistically different from zero. When the dealer receives fixed, the larger the notional and the longer the maturity are, the larger the swap return is in the non-CCP segment. Conversely, when the dealer pays fixed, the larger the notional the larger the discount, but the coefficients are generally not very significant in statistical terms.

More importantly, the results in Columns 1 to 4 point to the important role of the creditworthiness of dealers' counterparties. When the dealer sells (receives fixed), a more creditworthy customer enjoys a lower price, whereas when the dealer buys (pays fixed), a more creditworthy customer receives a better price. The credit rating coefficients of dealers' customers are statistically and economically significant: for instance, an A+ customer pays (receives) about 4 basis points lower (higher) swap rate than what an A- customer does (the difference in ratings is two notches) in the non-CCP segment.[29]

All in all, our findings shed light on the existence of OTC premia (i) generating more expensive non-CCP trades, (ii) decreasing with initial margins, and (iii) favouring dealers. Our results point to the pass-through of valuation adjustments from dealers to customers,

[29]Note that we do not include any interactions between the non-CCP dummy and ratings in Columns 5 to 8, because ratings are not available for non-banks.

in particular the CVA and KVA valuation adjustments.

4.4. Other results

In this subsection, we extend our analysis in two directions: first, we dig into the regulatory effects on IRS pricing by analysing the subset of firms exempted from the CVA capital charge (which is related to KVA). Second, we conduct additional tests to address the question whether other factors such as market liquidity and dealer-to-customer relationships can explain the OTC premium.

The main idea behind our analysis is that heterogeneity in derivative prices arises from a pass-through of dealers' inventory costs including regulatory charges on to market prices via XVA effects. Although our empirical findings are overall consistent with this conjecture, it is difficult to provide direct evidence of it for at least two reasons: first, there is no unique regulatory event in our sample period determining a clear change in behaviour of market participants.[30] Second, it is difficult to disentangle XVA effects; this is especially true for KVA and CVA because they depend on similar factors (see Section 2).[31] However, the asymmetric effect of Basel III on the different types of market participants, gives rise to an additional test to validate our conjecture. In fact, the European regulation exempted dealers' transactions from the calculation of the additional CVA capital charge creating KVA when they traded with pension funds, nonfinancial corporates below the clearing threshold, and public bodies.[32]

This exemption allows us to test the following hypothesis: if KVA drives the OTC premia, we expect them to be smaller or disappear when European dealers trade against the exempted firms. A relevant feature of the exempted firms is that they rarely exchange initial margin (in less than 0.2% of their trades in our sample), suggesting that dealers

[30]Most of the new banking regulations were already in the implementation stage when OTC derivatives data became available to regulators (in Europe in December 2014).

[31]Two-third of the respondents to a survey by *Risk* magazine in 2015 believed that overlaps between the KVA and CVA do exist.

[32]Regulation (EU) No 575/2013 (Article 382, point 4) and Regulation (EU) No 648/2012 (Article 1, point 4; and Article 2, point 10) of the European Parliament and of the Council.

remain exposed to some degree of counterparty risk when they trade against them. Thus, the absence of initial margins sharpens the identification of KVA because any evidence of reduction in the premium associated to exempted firms should be attributed to regulation-driven KVA rather than CVA.

We test this hypothesis by interacting the non-CCP variable in Eq. (1) with a dummy that equals one when the dealer's counterparty is an exempted entity.[33] Note that to perform this analysis, we focus on the dealer-to-non-bank client segment and remove 30 trades by non-EU dealers, as they were unaffected by the exemption. The regression results, which are summarised in Table 9, clearly show that there is a significant reduction in the OTC premium for exempted firms. Even if there can be other XVA effects involved, this result is consistent with the idea that KVA effects tend to materialise only if firms are actually affected by the new regulation. It is worth noting that this regression includes fixed effects controlling for the (smaller) size or other unobservable characteristics of the exempted firms. Since the exempted firms do not exchange initial margin, which would otherwise have reduced counterparty risk, the new results support the pricing of KVA.

We next turn the analysis to market liquidity, relationships, and bilateral exposures. By conducting these additional tests, we can also address the question whether there could be some unobservable variables providing additional explanations to the OTC premium. This unobservable variable should affect prices at the trade level, i.e., it must be specific to each counterparty and to day/time. Our empirical strategy already controls for this possibility by including time and counterparty fixed effects, time-varying counterparty credit risk, as well additional controls for dealers' balance sheets. Nonetheless, to err on the side of caution, in this section we conduct some additional analysis.

First, we consider the differences in market liquidity across segments. The idea that the OTC premium (fully) depends on market illiquidity seems implausible for at least

[33] We classified exempted entities as follows. Pension funds consist of all firms with the words "pension," "retirement," or "retirement scheme" in their name. Because there is no public information on clearing thresholds, we consider all nonfinancial counterparties as exempted. Finally, we select the remaining exempted entities manually. Overall, we identified 1,830 trades from about 80 exempted entities.

three reasons. First, the effect from liquidity should have been perfectly symmetric as dealers would charge half-spread every time they buy or sell a swap contract. But our results clearly show that this is not the case. Second, the finding that the premium is associated with the type of collateral in bilateral trades or the credit rating of clients is hard to be reconciled with the illiquidity hypothesis. Finally, the current specifications already include some controls for market liquidity such as the trade size (i.e., notional) and dealer characteristics (e.g., balance sheet variables) accounting for the propensity to provide liquidity.

We nonetheless proceed with a more direct test of the liquidity hypothesis. The basic idea is centered on the execution of swaps on centralised electronic platforms, which earlier literature has shown are associated with better liquidity. These platforms were introduced in February 2014 by the Dodd-Frank Act, which required US persons to execute centrally cleared interest rate swaps on multilateral pre-trade transparent venues, known as Swap Execution Facilities (SEF). By its very nature, the SEF mechanism reduces many frictions such as information asymmetry, search costs, and the dealer's bargaining power by providing more trading options to their customers. Benos et al. (2019) show that indeed SEF trading reduced effective spreads in the USD IRS market by about 25%.[34] Hence, if the OTC premium stems from market illiquidity, then the former should become insignificant once we control for the venue of execution (SEF trading). We test for this by introducing a dummy variable, 'SEF,' in specification 1, which equals one for centrally cleared transactions executed on SEFs and zero otherwise.[35] Table 9 presents the (baseline) results of the specification with the SEF dummy. Columns 1 to 4 show that the SEF dummy is negative and significant, which suggests that prices of trades executed on SEFs are on average

[34] SEFs facilitate multilateral trading by a central limit order book and a request-for-quote functionality. See Benos et al. (2019) for the institutional details. Riggs, Onur, Reiffen, and Zhu (2018) report that the use of limit order book on SEFs (for index CDS contracts) is limited. Note that the European equivalent of US-authorised SEF was introduced in January 2018 as part of the Markets in Financial Instruments Directive (MiFID) II implementation, which is outside our sample period.

[35] The European DTCC data do not contain a flag for the venue of execution. Therefore we had to ask LCH to provide us with this information for LCH trades (they account for 97% of centrally cleared trades in our sample). About one in five LCH trades were executed on SEF. Note that these trades involved non-US persons, who were not subject to the Dodd-Frank Act trading mandate.

closer to the end-of-day Bloomberg benchmark price. More importantly, the non-CCP dummy coefficients are almost unchanged compared to the ones in Table 6. This evidence is against the liquidity hypothesis: the premium does not seem to be a compensation for any differences in liquidity across the different OTC segments.

Another issue that might influence swap prices is the relationship between counterparties. For example, a dealer might have stronger negotiating power with some clients or offer them better prices if they do more business with her. Additionally, they might have different agreements in place to regulate their relationships with different clients, for example, the agreements that regulate the collateral held by two parties (credit support annex, CSA). Although prior research has not analysed the IRS market, previous papers show that relationships matter in some other OTC markets (e.g., Green, Li, and Schürhoff, 2010; Hendershott, Li, Livdan, and Schürhoff, 2017; and Di Maggio, Kermani, and Song, 2017). To conclude our analysis, we pose the question whether relationships can explain the OTC premia. To answer this question we modify Eq. (1) by replacing the buyer ID and seller ID fixed effects with their interaction. The new specification controls for any unobservable time-invariant effects at the pair of counterparties level (i.e., bilateral relationships). We present this specification in Columns 1 to 4 in Table 10. The results are qualitatively similar to the ones in Table 6, but bigger in magnitude in the case when the dealer receives fixed (sells protection).

We next allow for these relationships to vary over time. For example, the development of the bilateral dealer-client exposures might influence the decision to clear, the direction of trade (paying vs. receiving fixed), or the pricing of swaps. As a normal practice in trading derivatives, we expect that parties re-calculate these exposures on a monthly basis. We capture this effect by replacing δ_i and ζ_j in specification 1 with a month $\times$ buyer ID $\times$ seller ID fixed effect. As in many dealer-to-customer relationships, we assume that the average counterparty rebalances her portfolio at the monthly frequency and as a result, bilateral exposures change monthly. We present variations of this specification in Columns 5 to 8 of Table 10. In line with the results in the previous section, our two main findings still hold: first, when dealers receive fixed they charge a premium, and in fact, its magnitude is almost twice as much as the one in Table 6; second, there is no premium when dealers pay the fixed rate.[36]

To sum up, the results in this section corroborate the existence of OTC premia and dealer-customer asymmetric patterns, which are unaffected by market illiquidity, relationships, and time-varying bilateral exposures.

5. Conclusion

This paper provides the first systematic study of IRS by analysing the transitional regime after the introduction of price-based measures such as CVA capital charges but before the entry into force of the quantity-based European central clearing mandate in mid-2016. Using unique trade repository data at transaction and ID levels, we uncover the main distinguishing characteristics of transactions cleared via a central counterparty (CCP) with respect to those cleared bilaterally (non-CCP). A trade is more likely to be centrally cleared with larger (standardised) notional and longer maturity, and involving dealers, banks, and hedge funds rather than corporates and insurance companies. In terms of concentration of credit risk, the CCP (non-CCP) segment is more populated by market participants with higher (lower) creditworthiness. Moreover, credit risk concentration in the non-CCP segment increases in distressed markets, perhaps in reaction to CCP margin procyclicality.

Using panel regressions with fixed effects for time and counterparties' IDs, we conduct an in-depth analysis of the price heterogeneity of swap contracts. We find compelling evidence that prices differ across segments and market participants, and we call these price differentials OTC premia. OTC premia arise for decentralised clearing, riskier contracts and counterparties, and are economically important. For instance, when a dealer sells

[36] We also controlled for client-month fixed effects, which control for time-varying clients' exposures across counterparties and markets/products. The results survive.

interest rate protection to a client (i.e., the dealer receives fixed), the client pays the dealer around 8 basis points more for a non-CCP contract than an equivalent CCP one. This premium decreases when initial margin is posted. Another finding is that OTC premia favour dealers, especially if their customers are non-banks. Overall, our findings suggest that OTC premia reflect inventory costs possibly increased by recent regulations that are passed on to prices through the so-called valuation adjustments (XVA).

Considering that many markets continue to trade bilaterally and the implementation of the new regulation reforming derivatives markets is far to be completed, our study should deliver important insights for policy makers and market participants. For policy makers, it provides evidence that market participants in derivatives markets have adapted their trading behaviours and pricing in line with some declared objectives of new regulation designed to improve the resilience of OTC markets. In fact, our study shows that non-CCP swaps are more expensive while the CCP segment hosts market participants of better credit quality and features more standard contracts. However, evidence of price heterogeneity and dealers' bargaining power against their clients suggests that transparency and efficiency, which are also declared objectives, can be improved. For market participants, our paper should help identify OTC premia across market segments and market participants by quantifying the main determinants of derivative prices. This task is particularly relevant in the post-crisis regime in which XVAs presumably play a major role.

Finally, our findings call for future research to examine the impact of reforms that are outside our sample period, such as the European clearing mandate[37] and the uncleared margin rules,[38] or outside the financial instrument and market participants analysed in this paper.

[37]Inducing more demand for central clearing and the concentration in the provision of client clearing, this policy could overly increase central clearing costs.

[38]These rules (phased in between January 2017 and September 2020) are introducing stricter standards for the calculation of variation and initial margin (e.g., daily exchange of high quality collateral by both parties), which will presumably imply a more important role for the FVA and MVA and greater reduction in the CVA and KVA.

References

Abad, J., Aldasoro, I., Aymanns, C., D'Errico, M., Rousova, L. F., Hoffmann, P., Langfield, S., Neychev, M., Roukny, T., 2016. Shedding light on dark markets: First insights from the new EU-wide OTC derivatives dataset. Discussion paper, European Systemic Risk Board.

Acharya, V., Bisin, A., 2014. Counterparty risk externality: Centralized versus over-the-counter markets. Journal of Economic Theory 149, 153–182.

Adrian, T., Etula, E., Muir, T., 2014. Financial intermediaries and the cross-section of asset returns. Journal of Finance 69, 2557–2596.

Afonso, G., Lagos, R., 2015. Trade dynamics in the market for federal funds. Econometrica 83, 263–313.

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

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

Arora, N., Gandhi, P., Longstaff, F. A., 2012. Counterparty credit risk and the credit default swap market. Journal of Financial Economics 103, 280–293.

Atkeson, A. G., Eisfeldt, A. L., Weill, P.-O., 2015. Entry and exit in OTC derivatives markets. Econometrica 83, 2231–2292.

Babus, A., Hu, T.-W., 2017. Endogenous intermediation in over-the-counter markets. Journal of Financial Economics 125, 200–215.

Babus, A., Kondor, P., 2018. Trading and information diffusion in OTC markets. Econometrica 86, 1727–1769.

Bank for International Settlements, 2016a. OTC derivatives statistics at end-June 2016. Technical report.

Bank for International Settlements, 2016b. Triennial survey of foreign exchange and OTC derivatives trading. Technical report.

Basel Committee on Banking Supervision, 2009. Strengthening the resilience of the banking sector, consultative document. Technical report.

Bellia, M., Panzica, R., Pelizzon, L., Peltonen, T., 2018. The demand for central clearing: To clear or not to clear, that is the question. SAFE Working Paper No. 193.

Benos, E., Payne, R., Vasios, M., 2019. Centralized trading, transparency and interest rate swap market liquidity: evidence from the implementation of the Dodd-Frank Act. Journal of Financial and Quantitative Analysis (forthcoming).

Biais, B., Heider, F., Hoerova, M., 2012. Clearing, counterparty risk, and aggregate risk. IMF Economic Review 60, 193–222.

Biais, B., Heider, F., Hoerova, M., 2016. Risk-sharing or risk-taking? Counterparty risk, incentives, and margins. The Journal of Finance 71, 1669–1698.

Bolton, P., Santos, T., Scheinkman, J. A., 2016. Cream-skimming in financial markets. Journal of Finance 71, 105–137.

Brunnermeier, M. K., Pedersen, L. H., 2008. Market liquidity and funding liquidity. Review of Financial Studies 22, 2201–2238.

Cameron, A. C., Trivedi, P. K., 2010. Microeconometrics Using Stata, Revised Ed. Stata Press, College Station, Texas.

Cenedese, G., Della Corte, P., Wang, T., 2019. Currency mispricing and dealer balance sheets. Bank of England Staff Working Paper No. 779.

Cielinska, O., Joseph, A., Shreyas, U., Tanner, J., Vasios, M., 2017. Gauging market dynamics using trade repository data: The case of the Swiss franc de-pegging. Financial Stability Paper No. 41, Bank of England.

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

Du, W., Gadgil, S., Gordy, M. B., Vega, C., 2016. Counterparty risk and counterparty choice in the credit default swap market. Finance and Economics Discussion Series 2016-087.

Duffie, D., 2012. Dark Markets: Asset Pricing and Information Transmission in Over-the-Counter Markets. Princeton University Press, Princeton, NJ.

Duffie, D., Garleanu, N., Pedersen, L. H., 2005. Over-the-counter markets. Econometrica 73, 1815–1847.

Duffie, D., Garleanu, N., Pedersen, L. H., 2007. Valuation in over-the-counter markets. Review of Financial Studies 20, 1865–1900.

Duffie, D., Malamud, S., Manso, G., 2009. Information percolation with equilibrium search dynamics. Econometrica 77, 1513–1574.

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.

Financial Stability Board, 2010. Implementing OTC derivatives market reforms. Technical report.

Financial Stability Board, 2017a. OTC derivatives market reforms: Twelfth progress report on implementation. Technical report.

Financial Stability Board, 2017b. Review of OTC derivatives market reforms: Effectiveness and broader effects of the reforms. Technical report.

Financial Stability Board, 2018. Incentives to centrally clear over-the-counter (OTC) derivatives. Technical report.

Glode, V., Green, R. C., Lowery, R., 2012. Financial expertise as an arms race. Journal of Finance 67, 105–137.

Golosov, M., Lorenzoni, G., Tsyvinski, A., 2014. Decentralized trading with private information. Econometrica 82, 1055–1091.

Green, A., 2015. XVA: Credit, Funding and Capital Valuation Adjustments. John Wiley & Sons, Hoboken, New Jersey.

Green, R. C., Hollifield, B., Schürhoff, N., 2007. Financial intermediation and the costs of trading in an opaque market. Review of Asset Pricing Studies 20, 275–314.

Green, R. C., Li, D., Schürhoff, N., 2010. Price discovery in illiquid markets: Do financial asset prices rise faster than they fall? Journal of Finance 65, 1669–1702.

Gregory, J., 2015. The XVA Challenge: Counterparty Credit Risk, Funding, Collateral and Capital. John Wiley & Sons, Hoboken, New Jersey.

Grossman, S. J., Miller, M. H., 1986. Economic costs and benefits of the proposed one-minute time bracketing regulation. Journal of Futures Markets 6, 141–166.

Hau, H., Hoffmann, P., Langfield, S., Timmer, Y., 2018. Discriminatory pricing of over-the-counter derivatives. CEPR Discussion Paper No. DP12525.

He, Z., Kelly, B., Manela, A., 2017. Intermediary asset pricing: New evidence from many asset classes. Journal of Financial Economics 126, 1–35.

He, Z., Krishnamurthy, A., 2013. Intermediary asset pricing. American Economic Review 103, 732–770.

Hendershott, T., Li, D., Livdan, D., Schürhoff, N., 2017. Relationship trading in OTC markets. Swiss Finance Institute Research Paper No. 17-30.

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

Hull, J., Predescu, M., White, A., 2005. Bond prices, default probabilities and risk premiums. Journal of Credit Risk 1, 53–60.

Jankowitsch, R., Nashikkar, A., Subrahmanyam, M., 2011. Price dispersion in OTC markets: A new measure of liquidity. Journal of Banking and Finance 35, 343–357.

Lagos, R., Rocheteau, G., 2007. Search in asset markets: Market structure, liquidity, and welfare. American Economic Review 97, 198–202.

Lagos, R., Rocheteau, G., 2009. Liquidity in asset markets with search frictions. Econometrica 77, 403–426.

Li, D., Schürhoff, N., 2019. Dealer networks. Journal of Finance 74, 91–144.

Loon, Y. C., 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, 91–115.

Loon, Y. C., Zhong, Z. K., 2016. Does Dodd-Frank affect OTC transaction costs and liquidity? Evidence from real-time CDS trade reports. Journal of Financial Economics 119, 645–672.

Menkveld, A. J., 2017. Crowded positions: An overlooked systemic risk for central clearing parties. Review of Asset Pricing Studies 7, 209–242.

Mildenstein, E., Schleef, H., 1983. The optimal pricing policy of a monopolistic market-maker in the equity market. The Journal of Finance 38, 218–231.

Murphy, D., Vasios, M., Vause, N., 2014. An investigation into the procyclicality of risk-based initial margin models. Financial Stability Paper No. 29, Bank of England.

O'Hara, M., Oldfield, G. S., 1986. The microeconomics of market making. Journal of Financial and Quantitative Analysis 21, 361–376.

Pelizzon, L., Subrahmanyam, M. G., Tomio, D., Uno, J., 2016. Sovereign credit risk, liquidity, and European Central Bank intervention: Deus ex machina? Journal of Financial Economics 122, 86–115.

Riggs, L., Onur, E., Reiffen, D., Zhu, H., 2018. Swap trading after Dodd-Frank: Evidence from index CDS. Unpublished working paper, Commodity Futures Trading Commission and Massachusetts Institute of Technology.

Ruiz, I., 2015. XVA Desks – A New Era for Risk Management. Palgrave Macmillan UK, London.

Shen, P., Starr, R. M., 2002. Market-makers' supply and pricing of financial market liquidity. Economics Letters 76, 53–58.

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

Zhu, H., 2012. Finding a good price in opaque over-the-counter markets. Review of Financial Studies 25, 1255–1285.

Fig. 1. Daily notional traded (in $billion) by segment. In this figure we plot the total notional traded in the CCP and non-CCP segment. The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016.

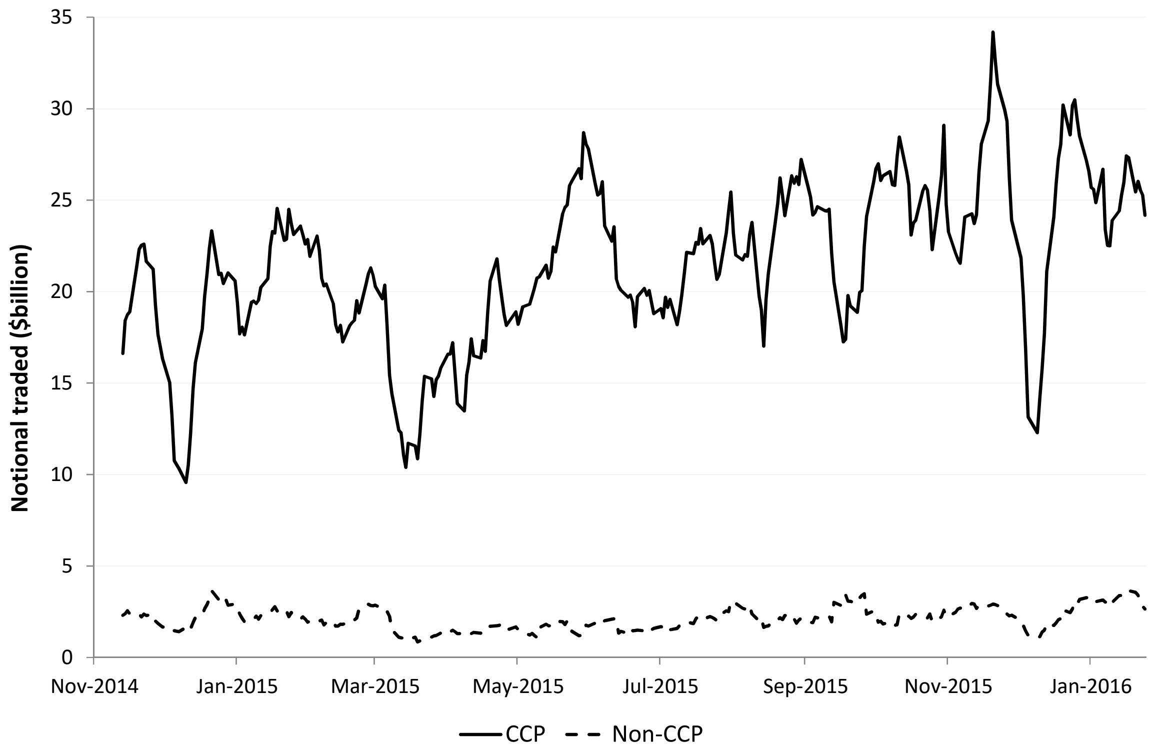


Table 1
Trading activity by segment and counterparty type.

This table reports the number of trades (N trades) and notional traded (Notional) throughout our sample period by segment and counterparty type. CCP denotes trades cleared through a central counterparty, while Non-CCP denotes non-centrally cleared trades. The latter segment consists of collateralised (Non-CCP with margin) and uncollateralised (Non-CCP no margin) trades. The exchanged collateral can be variation margin or/and initial margin. Counterparties are classified into asset managers (AM), banks (Bank), dealers (Dealer), hedge funds (HF), insurance companies and pension funds (Ins), other financial companies (Other fin), and nonfinancial companies (Non-fin). Panel B excludes trades from entities that could not be classified. The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016.

Panel A: Breakdown by segment

	N trades	Notional ($m)
CCP	85,810	6,801,165
Non-CCP	15,241	669,346
Total	101,051	7,470,511

Panel B: Breakdown by segment and counterparty type

	AM	Bank	Dealer	HF	Ins	Other fin	Non-fin
CCP							
N trades	3,324	33,387	114,733	8,057	300	171	26
Notional ($m)	132,823	1,831,592	9,084,860	1,074,940	21,561	11,100	1,216
Non-CCP with margin							
N trades	1,045	4,869	11,966	610	797	696	113
Notional ($m)	35,133	132,296	560,238	81,574	70,474	44,364	9,573
Non-CCP no margin							
N trades	635	980	3,717	56	270	177	28
Notional ($m)	14,192	37,631	149,484	5,904	17,787	21,621	7,365

Table 2
Summary statistics by trade — breakdown by segment.

This table reports summary statistics (by trade) of the main variables used in our analysis split by segment. CCP denotes trades cleared through a central counterparty, while Non-CCP denotes non-centrally cleared trades. The latter segment consists of collateralised (Non-CCP with margin) and uncollateralised (Non-CCP no margin) trades. Notional is the dollar amount (in $m) on which the exchanged interest payments are based. Maturity refers to the number of years between the effective and maturity date of the swap contract. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. The credit rating is the average credit rating of the receiver (seller) or payer (buyer) of fixed rate from three different sources (S&P, Moody's, and Fitch). It has been converted to a scale from 0 to 20, where 0 denotes the worst rating and 20 the maximum rating (see Table A.2 in the Internet Appendix). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016.

	N	Mean	Std. dev.
Panel A: CCP			
Notional ($m)	85,810	79.26	152.23
Log-notional	85,810	17.36	1.40
Maturity (years)	85,810	9.48	8.31
Swap return (bps)	85,803	1.78	16.67
Credit rating of buyer	57,593	14.66	1.20
Credit rating of seller	57,593	14.73	1.25
Panel B: Non-CCP			
Notional ($m)	15,241	43.92	126.82
Log-notional	15,241	16.27	1.80
Maturity (years)	15,241	8.23	6.76
Swap return (bps)	15,237	2.27	20.70
Credit rating of buyer	3,823	14.55	1.77
Credit rating of seller	3,823	14.13	1.75
Panel C: Non-CCP with margin			
Notional ($m)	11,658	45.05	122.85
Log-notional	11,658	16.40	1.68
Maturity (years)	11,658	8.20	6.77
Swap return (bps)	11,654	2.19	19.32
Credit rating of buyer	3,267	14.49	1.74
Credit rating of seller	3,267	14.20	1.74
Panel D: Non-CCP no margin			
Notional ($m)	3,583	40.22	138.93
Log-notional	3,583	15.86	2.12
Maturity (years)	3,583	8.31	6.73
Swap return (bps)	3,583	2.52	24.69
Credit rating of buyer	556	14.94	1.92
Credit rating of seller	556	13.72	1.75

Table 3

Determinants of (de)centralised clearing — contract characteristics

This table reports the results of a probit regression, where the dependent variable is one for non-centrally cleared trades and zero otherwise. Log-notional is the logarithm of the dollar amount on which the contract's exchanged interest payments are based. Maturity refers to the number of years between the effective and maturity date of the swap contract. Standardised maturity is a dummy variable that is one when the contract's maturity is 1Y, 2Y, 3Y, 4Y, . . . , 50Y and zero otherwise. Standardised price is a dummy variable that is one when the contract price's last digit is 5 or 0. For example, a 5Y swap with 1.05 fixed rate has a standardised maturity and price. The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. Robust t-statistics are shown in brackets. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	(1)	(2)	(3)
Log-notional	-0.281***		-0.282***
	(-73.17)		(-73.07)
Maturity	-0.028***		-0.028***
	(-36.54)		(-35.98)
Standardised maturity		-0.216***	-0.267***
		(-13.63)	(-16.14)
Standardised price		-0.143***	-0.089***
		(-14.25)	(-8.42)
Constant	3.985***	-0.785***	4.264***
	(59.02)	(-51.94)	(61.19)
Pseudo R^2	0.092	0.005	0.096
Obs	101051	101051	101051

Table 4

Determinants of (de)centralised clearing — counterparty characteristics

This table reports the results of a probit regression, where the dependent variable is one for non-centrally cleared trades and zero otherwise. The regression is run at the trade and counterparty level for specifications (1) to (4) and trade-only level for specifications (5) to (6). Log-notional is the logarithm of the dollar amount on which the contract's exchanged interest payments are based. Maturity refers to the number of years between the effective and maturity date of the swap contract. The next seven regressors are dummy variables that capture the different counterparty types. For example, Asset manager equals one if the counterparty is an asset manager and zero otherwise. CM/CCP client is one if the counterparty is either a clearing member or has a client account with a CCP and zero otherwise. CCP client is one if the counterparty has a client account with a CCP and zero otherwise. D2C is a dummy variable that is one if the transaction is executed in the dealer-to-client segment and zero otherwise. The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. Robust t-statistics are shown in brackets. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
Log-notional		-0.271***		-0.255***		-0.237***
		(-97.22)		(-91.52)		(-62.88)
Maturity		-0.028***		-0.027***		-0.023***
		(-50.52)		(-47.90)		(-28.46)
Asset manager	0.158***	-0.037				
	(7.50)	(-1.59)				
Bank	-0.458***	-0.420***				
	(-35.11)	(-30.38)				
Dealer	-0.591***	-0.475***				
	(-51.79)	(-38.64)				
Hedge fund	-0.848***	-0.510***				
	(-37.80)	(-21.05)				
Insurance	1.356***	1.562***				
	(34.53)	(35.59)				
Nonfinancial	1.595***	1.764***				
	(13.53)	(13.75)				
Other financial	1.561***	1.656***				
	(32.85)	(33.24)				
CM/CCP client			-1.267***	-1.195***		
			(-133.66)	(-120.35)		
CCP client			0.173***	0.134***		
			(15.97)	(11.67)		
D2C					1.227***	1.089***
					(78.55)	(67.01)
Constant	-0.582***	4.168***	0.003	4.511***	-1.998***	2.320***
	(-55.49)	(84.11)	(0.36)	(90.26)	(-136.59)	(33.96)
Pseudo R^2	0.057	0.137	0.104	0.176	0.104	0.164
Obs	202102	202102	202102	202102	101051	101051

Table 5

Determinants of (de)centralised clearing — counterparty credit risk.

This table reports the results of a probit regression, where the dependent variable is one for non-centrally cleared trades and zero otherwise. The regression is run either at the trade and counterparty level (Columns 1 to 4) or only the trade level (Columns 5 and 6). Log-notional is the logarithm of the dollar amount on which the contract's exchanged interest payments are based. Maturity refers to the number of years between the effective and maturity date of the swap contract. Credit rating is the counterparty's credit rating from three different sources (S&P, Moody's, and Fitch). It has been converted to a scale from 0 to 20, where 0 denotes the worst rating and 20 the maximum rating (see Table A.2 in the Internet Appendix). VIX is the volatility implied by S&P 500 index options. Libor-OIS spread is the difference between the three-month USD Libor rate and the Overnight Index Swap rate, which is commonly used as a proxy for the cost of funding. The changes in the last two variables are used to capture market stresses. The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. Robust t-statistics are shown in brackets. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Log-notional	-0.294***	-0.293***	-0.295***	-0.295***	-0.281***	-0.282***
	(-83.73)	(-83.54)	(-83.83)	(-83.83)	(-73.17)	(-73.17)
Maturity	-0.031***	-0.031***	-0.031***	-0.031***	-0.028***	-0.028***
	(-44.78)	(-44.53)	(-44.92)	(-44.93)	(-36.52)	(-36.55)
Credit rating	-0.024***					
	(-6.69)					
$0 \leq$ Rating < 11		0.884***				
		(12.55)				
$11 \leq$ Rating < 15			0.072***			
			(8.40)			
$15 \leq$ Rating ≤ 20				-0.083***		
				(-9.76)		
VIX changes					0.238***	
					(4.37)	
Libor-OIS spread changes						0.428***
						(4.08)
Constant	4.416***	4.059***	4.049***	4.126***	3.985***	3.988***
	(54.83)	(65.78)	(65.56)	(66.55)	(59.01)	(59.02)
Pseudo R^2	0.093	0.094	0.093	0.093	0.092	0.092
Obs	162348	162348	162348	162348	101051	101051

Table 6
OTC premium in dealer-to-client segment.

The table reports the results of trade-level panel regressions of the swap return on the Non-CCP dummy that equals one for non-CCP trades and zero otherwise, and a number of other variables and controls. We only include trades executed in the dealer-to-client segment. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. Non-CCP with IM is a dummy that equals one for non-centrally cleared trades that involve the exchange of initial margin by the two counterparties and zero otherwise. CR and LR denote the capital ratio and the leverage ratio, respectively. The rest of the variables are defined in Eqs. (1) and (2). Columns 1–4 show the results when the dealer sells interest rate protection (receives fixed), while Columns 5–8 show the results when the dealer buys protection (pays fixed). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties reported to DTCC between December 1, 2014 and February 19, 2016. All specifications include time, buyer ID, and seller ID fixed effects. We report t-statistics calculated using clustered standard errors (by quarter and dealer ID) in parentheses. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	Dealer receiving fixed				Dealer paying fixed			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-CCP dummy	8.116**	8.424***	9.189***	8.621***	1.840	6.426	1.817	6.615
	(2.52)	(2.73)	(2.65)	(2.78)	(0.88)	(1.46)	(0.84)	(1.39)
Non-CCP with IM			-3.800**	-9.369***			0.729	-2.828
			(-2.22)	(-3.82)			(0.21)	(-0.51)
Log-notional	0.113	-0.022	0.104	-0.021	-0.288	-0.206	-0.287	-0.206
	(0.78)	(-0.12)	(0.72)	(-0.11)	(-1.41)	(-0.64)	(-1.41)	(-0.63)
Maturity	0.024	0.023	0.022	0.023	0.033	0.063	0.033	0.063
	(0.91)	(0.70)	(0.85)	(0.68)	(1.20)	(1.56)	(1.20)	(1.56)
Credit rating of buyer	0.431	0.684	0.425	0.685	-0.381	-0.592	-0.382	-0.586
	(1.17)	(1.10)	(1.16)	(1.10)	(-0.66)	(-0.75)	(-0.66)	(-0.74)
Credit rating of seller	0.375	0.275	0.393	0.268	0.203	0.542	0.204	0.541
	(0.79)	(0.45)	(0.84)	(0.44)	(0.78)	(0.74)	(0.78)	(0.74)
CR of dealer (payer)						-0.846***		-0.848***
						(-3.43)		(-3.44)
CR of dealer (receiver)		0.006		0.012				
		(0.03)		(0.06)				
LR of dealer (payer)						0.226		0.227
						(0.97)		(0.97)
LR of dealer (receiver)		0.254		0.260				
		(1.49)		(1.56)				
Day, Buyer ID, Seller ID FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\overline{R}^2$	0.177	0.163	0.178	0.163	0.267	0.279	0.267	0.279
Obs	12092	7119	12092	7119	16193	8093	16193	8093

Table 7
OTC premium in dealer-to-client segment, when clients are not banks.

The table reports the results of trade-level panel regressions of the swap return on the Non-CCP dummy that equals one for non-centrally cleared trades and zero otherwise, and a number of other variables and controls. We only include trades executed in the dealer-to-non-bank-client segment. Non-banks consist of hedge funds, asset managers, insurance, and nonfinancial firms. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. Non-CCP with IM is a dummy that equals one for non-centrally cleared trades that involve the exchange of initial margin by the two counterparties and zero otherwise. CR and LR denote the capital ratio and the leverage ratio, respectively. The rest of the variables are defined in Eqs. (1) and (2). Columns 1–4 show the results when the dealer sells interest rate protection (receives fixed), while Columns 5–8 show the results when the dealer buys protection (pays fixed). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. All specifications include time, buyer ID, and seller ID fixed effects. We report t-statistics calculated using clustered standard errors (by quarter and dealer ID) in parentheses. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	Dealer receiving fixed				Dealer paying fixed			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-CCP dummy	4.148**	4.190	4.159**	3.739*	-0.081	-2.762*	-0.028	-0.005
	(2.03)	(1.44)	(2.03)	(1.77)	(-0.08)	(-1.74)	(-0.03)	(-0.01)
Non-CCP with IM			-1.933	-1.467			-5.714	-5.796
			(-1.50)	(-1.37)			(-0.73)	(-0.75)
Log-notional	0.356**	0.200	0.356**	0.360**	0.246	-0.054	0.247	0.287
	(2.11)	(0.84)	(2.10)	(2.04)	(1.26)	(-0.20)	(1.27)	(1.48)
Maturity	0.029	0.029	0.029	0.023	0.036	0.142***	0.037	0.037
	(0.86)	(0.52)	(0.86)	(0.64)	(0.65)	(2.81)	(0.65)	(0.66)
Credit rating of buyer						-1.359		-0.604
						(-0.87)		(-0.71)
Credit rating of seller		0.956		1.462**				
		(0.80)		(2.41)				
CR of dealer (buyer)						-0.246		-0.440
						(-0.32)		(-1.15)
CR of dealer (seller)		0.554		0.779				
		(1.02)		(1.60)				
LR of dealer (buyer)						0.252		
						(0.80)		
LR of dealer (seller)		0.166						
		(0.79)						
Day, Buyer ID, Seller ID FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\overline{R}^2$	0.260	0.276	0.260	0.260	0.286	0.359	0.286	0.253
Obs	17651	10566	17651	16979	13394	5264	13394	13016

Table 8

OTC premium in dealer-to-client segment — determinants.

The table reports the results of trade-level panel regressions of the swap return on the Non-CCP dummy that equals one for non-centrally cleared trades and zero otherwise, and a number of interaction variables and controls. We report separate results for the dealer-to-client and the dealer-to-non-bank-client segment and for when the dealer sells (receives fixed) or buys (pays fixed) interest rate protection. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. CR and LR denote the capital ratio and the leverage ratio, respectively. The rest of the variables are defined in Eq. (1). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. All specifications include time, buyer ID, and seller ID fixed effects. We report t-statistics calculated using clustered standard errors (by quarter and dealer ID) in parentheses. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	Dealer-to-client				Dealer-to-client (non-bank)			
	Dealer receiving fixed		Dealer paying fixed		Dealer receiving fixed		Dealer paying fixed	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-CCP dummy	11.798	-36.498	-29.896	-91.455	-8.231	-13.610	-0.335	-1.250
	(0.41)	(-0.88)	(-0.79)	(-1.13)	(-1.37)	(-1.61)	(-0.05)	(-0.18)
Non-CCP × Log-notional	1.033	2.492	-1.267	-0.338	0.697**	1.027**	0.051	-0.026
	(1.30)	(1.61)	(-0.95)	(-0.15)	(2.12)	(2.21)	(0.14)	(-0.08)
Non-CCP × Maturity	0.494	1.255**	0.500	2.220***	0.040	0.013	-0.077	-0.124
	(1.55)	(2.14)	(1.25)	(3.16)	(0.58)	(0.11)	(-1.01)	(-1.51)
Non-CCP × Credit rating of buyer	-2.054*	-1.764*	2.030	2.923				
	(-1.73)	(-1.72)	(0.89)	(0.73)				
Non-CCP × Credit rating of seller	0.651	1.572	1.374**	2.899*				
	(0.90)	(1.38)	(2.22)	(1.73)				
Log-notional	0.019	-0.119	-0.158	-0.195	0.200	-0.044	0.242	-0.033
	(0.13)	(-0.73)	(-1.03)	(-0.84)	(0.96)	(-0.15)	(1.09)	(-0.11)
Maturity	0.000	-0.011	0.019	0.013	0.017	0.018	0.046	0.161**
	(0.02)	(-0.44)	(0.93)	(0.44)	(0.43)	(0.28)	(0.73)	(2.65)
Credit rating of buyer	0.433	0.778	-0.608	-0.762				-1.359
	(1.16)	(1.24)	(-1.02)	(-1.05)				(-0.86)
Credit rating of seller	0.222	0.097	0.242	0.497		0.951		
	(0.45)	(0.16)	(0.88)	(0.69)		(0.79)		
CR of dealer (payer)				-0.841***				-0.260
				(-3.23)				(-0.34)
CR of dealer (receiver)		-0.049				0.537		
		(-0.22)				(0.99)		
LR of dealer (payer)				0.244				0.251
				(1.11)				(0.80)
LR of dealer (receiver)		0.236				0.168		
		(1.48)				(0.79)		
Day, Buyer ID, Seller ID FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\overline{R}^2$	0.182	0.174	0.271	0.298	0.261	0.277	0.286	0.359
Obs	12092	7119	16193	8093	17651	10566	13394	5264

Table 9
OTC premium in dealer-to-client segment — liquidity and exempted firms.

The table reports the results of trade-level panel regressions of the swap return on the Non-CCP dummy that equals one for non-centrally cleared trades and zero otherwise, and a number of other variables and controls. We only include trades executed in the dealer-to-client segment. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. CR and LR denote the capital ratio and the leverage ratio, respectively. The other variables are defined in Eq. (1). Columns 1–4 show the results when the SEF variable, which equals one for centrally cleared trades executed on swap execution facilities and zero otherwise, is included. SEF captures differences in market liquidity. Columns 5–10 show the results for dealer-to-non-bank client segment, when we interact the non-CCP dummy with another dummy that is equal to one when the firm is exempted from the calculation of the CVA capital charge. We report results for when the dealer sells (receives fixed) or buys (pays fixed) interest rate protection. The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. Unless otherwise stated, specifications include time, buyer ID, and seller ID fixed effects. We report t-statistics calculated using clustered standard errors (by quarter and dealer ID) in parentheses. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	Liquidity				Exempted firms					
	Dealer receiving fixed		Dealer paying fixed		Dealer receiving fixed			Dealer paying fixed		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Non-CCP dummy	7.991**	7.786**	1.167	5.495	4.331**	4.226*	4.201	-1.038	-1.029	-2.727*
	(2.49)	(2.54)	(0.57)	(1.29)	(2.04)	(1.97)	(1.44)	(-1.06)	(-1.06)	(-1.71)
SEF	-3.580***	-4.896***	-4.556***	-5.755***						
	(-5.20)	(-4.62)	(-6.26)	(-5.02)						
Exempted*Non-CCP dummy					-5.481**	-5.265**	-2.205	5.655***	5.641***	-3.831
					(-2.25)	(-2.15)	(-0.67)	(3.75)	(3.75)	(-0.63)
Log-notional	0.155	0.070	-0.163	-0.046	0.353**	0.354**	0.199	0.246	0.247	-0.057
	(1.07)	(0.38)	(-0.81)	(-0.15)	(2.09)	(2.09)	(0.84)	(1.26)	(1.27)	(-0.21)
Maturity	0.033	0.037	0.051*	0.081**	0.029	0.028	0.028	0.036	0.036	0.144***
	(1.29)	(1.15)	(1.97)	(2.20)	(0.85)	(0.82)	(0.51)	(0.65)	(0.64)	(2.81)
Credit rating of buyer	0.446	0.843	-0.560	-0.813					-0.055	-1.393
	(1.19)	(1.32)	(-0.96)	(-1.02)					(-0.08)	(-0.89)
Credit rating of seller	0.247	0.118	0.188	0.545		0.881*	0.956			
	(0.52)	(0.19)	(0.72)	(0.75)		(1.91)	(0.80)			
CR of dealer (payer)				-0.853***						-0.256
				(-3.42)						(-0.34)
CR of dealer (receiver)		0.023					0.553			
		(0.10)					(1.02)			
LR of dealer (payer)				0.212						0.253
				(0.96)						(0.80)
LR of dealer (receiver)		0.246					0.166			
		(1.43)					(0.79)			
Day, Buyer ID, Seller ID FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
$\overline{R}^2$	0.185	0.177	0.274	0.289	0.260	0.261	0.276	0.287	0.287	0.359
Obs	12092	7119	16193	8093	17649	17622	10565	13364	13352	5242

Table 10

OTC premium in dealer-to-client segment — relationships and bilateral exposures.

The table reports the results of trade-level panel regressions of the swap return on the Non-CCP dummy that equals one for non-centrally cleared trades and zero otherwise, and a number of other variables and controls. We only include trades executed in the dealer-to-client segment. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. CR and LR denote the capital ratio and the leverage ratio, respectively. The other variables are defined in Eq. (1). Columns 1–4 show the results when buyer ID and seller ID fixed effects are replaced by their interaction. Columns 5–8 report results when the buyer ID and seller ID fixed effects are replaced by a month × buyer ID × seller ID fixed effect. Intuitively, this fixed effect captures bilateral dealer-client exposures that are assumed to change monthly. We report results for when the dealer sells (receives fixed) or buys (pays fixed) interest rate protection. The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. We report t-statistics calculated using clustered standard errors (by quarter and dealer ID) in parentheses. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	Relationships				Bilateral exposures (monthly)			
	Dealer receiving fixed		Dealer paying fixed		Dealer receiving fixed		Dealer paying fixed	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Non-CCP dummy	10.445***	12.993***	0.120	5.137	13.294**	15.390**	-0.862	1.657
	(2.67)	(2.82)	(0.05)	(0.87)	(2.13)	(2.10)	(-0.20)	(0.18)
Log-notional	0.054	-0.054	-0.275	-0.163	0.094	0.080	-0.446**	-0.560
	(0.33)	(-0.31)	(-1.32)	(-0.52)	(0.54)	(0.35)	(-2.19)	(-1.68)
Maturity	0.001	0.015	0.035	0.068*	0.000	0.001	0.003	0.017
	(0.04)	(0.45)	(1.30)	(1.75)	(0.00)	(0.04)	(0.10)	(0.41)
Credit rating of buyer	0.331	0.645	-0.565	-1.046	0.762	-0.346	0.363	-8.054
	(0.77)	(0.95)	(-0.84)	(-1.11)	(0.45)	(-0.27)	(0.28)	(-0.24)
Credit rating of seller	0.198	0.009	0.273	1.491**	-0.940	-5.348*	0.333	3.211
	(0.40)	(0.01)	(0.97)	(2.51)	(-0.38)	(-1.68)	(0.39)	(0.23)
CR of dealer (payer)				-0.850***				-1.150
				(-2.84)				(-0.47)
CR of dealer (receiver)		-0.059				-1.814*		
		(-0.24)				(-1.79)		
LR of dealer (payer)				0.136				1.727
				(0.52)				(1.05)
LR of dealer (receiver)		0.265				-0.132		
		(1.59)				(-1.60)		
Day, (Buyer ID × Seller ID) FE	Yes	Yes	Yes	Yes	No	No	No	No
Day, (Month × Buyer ID × Seller ID) FE	No	No	No	No	Yes	Yes	Yes	Yes
$\overline{R}^2$	0.236	0.188	0.353	0.332	0.432	0.361	0.505	0.490
Obs	12092	7119	16193	8093	12092	7119	16193	8093

Internet Appendix to

"OTC Premia"

by Gino Cenedese, Angelo Ranaldo, and Michalis Vasios

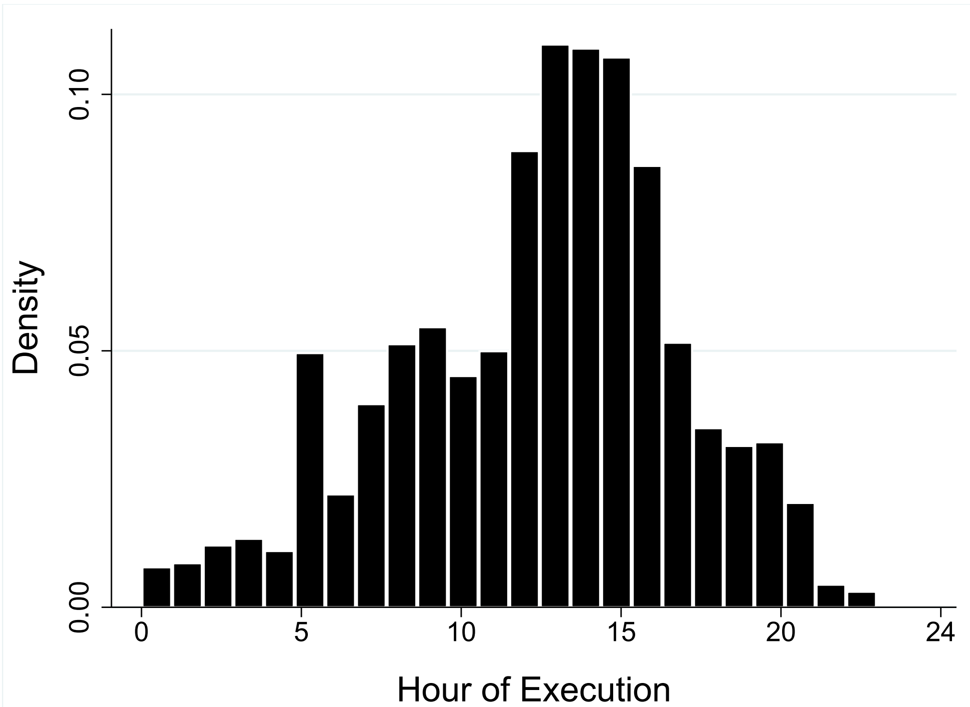
(not for publication)

Abstract

This appendix presents supplementary results not included in the main body of the paper.

Fig. A.1. Intraday distribution of transactions. The chart displays the empirical distribution of bilateral and centrally cleared transactions grouped in hourly baskets. Hours are indicated in Coordinated Universal Time (UTC). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016.

(a) Non-centrally cleared.



(b) Centrally cleared.

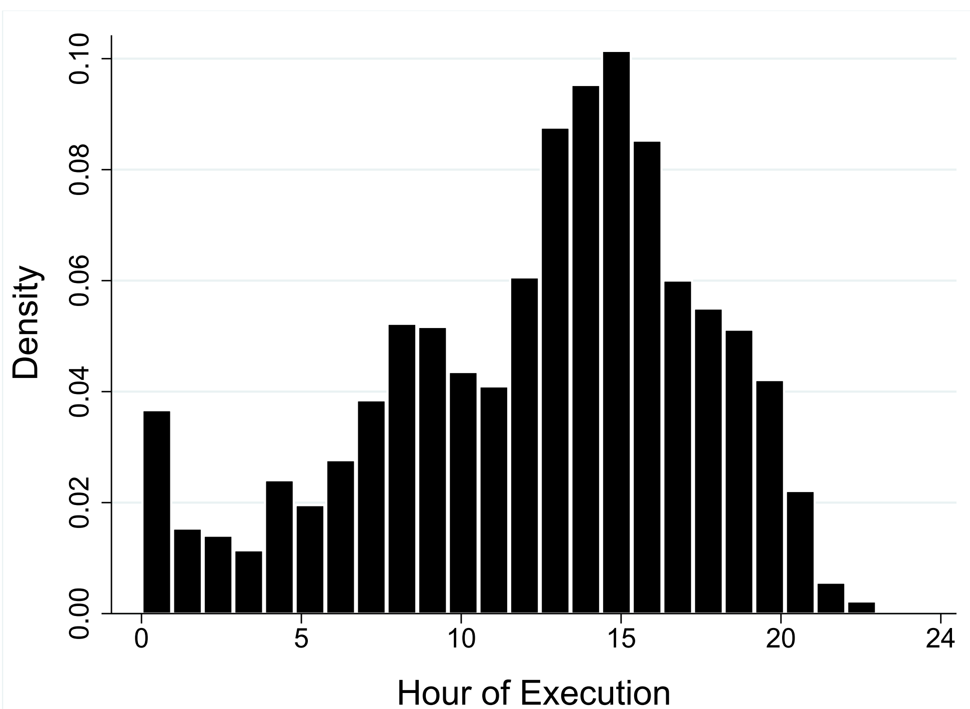


Table A.1
Trading activity by counterparty location.

The sample covers every USD-denominated spot vanilla interest rate swap which was reported to DTCC between December 1, 2014 and February 19, 2016. Transactions with an identifiable US-based counterparty are excluded. Percentages may not add up to 100 because of rounding.

	Transactions		Notional	
Location	Number	Percent	USD millions	Percent
United Kingdom	103,247	51%	8,477,820	57%
France	26,807	13%	1,807,937	12%
Germany	17,973	9%	1,289,611	9%
Cayman Islands	11,109	5%	1,152,110	8%
Canada	4,825	2%	388,458	3%
Switzerland	4,284	2%	325,517	2%
Japan	3,891	2%	188,035	1%
Hong Kong	1,850	1%	123,025	1%
Australia	2,799	1%	100,373	1%
Other Countries	15,329	8%	608,705	4%
Unclassified	9,988	5%	479,433	3%

Table A.2
Ratings conversion.

Rating			Conversion Scale
S&P	Moody's	Fitch	
AAA	Aaa	AAA	20
AA+	Aa1	AA+	19
AA	Aa2	AA	18
AA-	Aa3	AA-	17
A+	A1	A+	16
A	A2	A	15
A-	A3	A-	14
BBB+	Baa1	BBB+	13
BBB	Baa2	BBB	12
BBB-	Baa3	BBB-	11
BB+	Ba1	BB+	10
BB	Ba2	BB	9
BB-	Ba3	BB-	8
B+	B1	B+	7
B	B2	B	6
B-	B3	B-	5
CCC+	Caa1	CCC+	4
CCC	Caa2	CCC	3
CCC-	Caa3	CCC-	2
CC	Ca	CC	1
C	Ca	C	0.5
	C	DDD	0
D		DD	0
		D	0

Table A.3
Determinants of (de)centralised clearing — counterparty credit risk, excluding counterparties that do not have access to central clearing services.

This table reports the results of a probit regression, where the dependent variable is one for non-centrally cleared trades and zero otherwise. We exclude from the data counterparties that do not have access to central clearing services. The regression is run at the trade and counterparty level (columns 1 to 4). Log-notional is the logarithm of the dollar amount on which the contract's exchanged interest payments are based. Maturity refers to the number of years between the effective and maturity date of the swap contract. Credit rating is the counterparty's credit rating from three different sources (S&P, Moody's, and Fitch). It has been converted to a scale from 0 to 20, where 0 denotes the worst rating and 20 the maximum rating (see Table A.2 in the Internet Appendix). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties, which was reported to DTCC between December 1, 2014 and February 19, 2016. Robust t-statistics are shown in brackets. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	(1)	(2)	(3)	(4)
Log-notional	-0.286***	-0.285***	-0.286***	-0.286***
	(-80.29)	(-80.11)	(-80.36)	(-80.36)
Maturity	-0.029***	-0.029***	-0.029***	-0.029***
	(-41.80)	(-41.60)	(-41.93)	(-41.93)
Credit rating	-0.008**			
	(-2.10)			
$0 \leq$ Rating < 11		0.766***		
		(10.17)		
$11 \leq$ Rating < 15			0.062***	
			(7.08)	
$15 \leq$ Rating ≤ 20				-0.071***
				(-8.12)
Constant	3.986***	3.862***	3.854***	3.920***
	(49.08)	(61.81)	(61.61)	(62.43)
Pseudo R^2	0.088	0.089	0.088	0.089
Obs	160935	160935	160935	160935

Table A.4
OTC premium in dealer-to-client segment, controlling for hour fixed effects.

The table reports the results of trade-level panel regressions of the swap return on the Non-CCP dummy that equals one for non-CCP trades and zero otherwise, and a number of other variables and controls. We only include trades executed in the dealer-to-client segment. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. Non-CCP with IM is a dummy that equals one for non-centrally cleared trades that involve the exchange of initial margin by the two counterparties and zero otherwise. The rest of the variables are defined in Eqs. (1) and (2) in the main text. Columns 1–4 show the results when the dealer sells interest rate protection (receives fixed), while Columns 5–8 show the results when the dealer buys protection (pays fixed). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties reported to DTCC between December 1, 2014 and February 19, 2016. All specifications include time, buyer ID, and seller ID fixed effects. We report t-statistics calculated using clustered standard errors (by quarter and dealer ID) in parentheses. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	Dealer receiving fixed		Dealer paying fixed	
	(1)	(2)	(3)	(4)
Non-CCP dummy	8.241***	8.322***	1.599	6.089
	(2.63)	(2.91)	(0.77)	(1.43)
Log-notional	0.074	-0.049	-0.332	-0.197
	(0.48)	(-0.24)	(-1.54)	(-0.60)
Maturity	0.017	0.016	0.023	0.058
	(0.65)	(0.47)	(0.85)	(1.46)
Credit rating of buyer	0.318	0.538	-0.132	0.188
	(0.89)	(0.89)	(-0.22)	(0.21)
Credit rating of seller	0.570	0.795	0.270	0.547
	(1.14)	(1.11)	(1.03)	(0.75)
CR of dealer (payer)				-0.991***
				(-4.57)
CR of dealer (receiver)		-0.102		
		(-0.55)		
LR of dealer (payer)				0.259
				(1.00)
LR of dealer (receiver)		0.253		
		(1.54)		
Hour, Day, Buyer ID, Seller ID FE	Yes	Yes	Yes	Yes
$\overline{R}^2$	0.194	0.182	0.281	0.294
Obs	12092	7119	16193	8093

Table A.5
OTC premium in dealer-to-client segment, when clients are not banks, excluding entities with unclassified location.

The table reports the results of trade-level panel regressions of the swap return on the Non-CCP dummy that equals one for non-centrally cleared trades and zero otherwise, and a number of other variables and controls. We only include trades executed in the dealer-to-non-bank-client segment and exclude trades with entities with unclassified location. Non-banks consist of hedge funds, asset managers, insurance and non-financial firms. The swap return is defined as the difference (in bps) between the transaction-level swap rate and the mid-quote of the Bloomberg benchmark rate at the end of the previous business day. The rest of variables are defined in Eqs. (1) and (2). Columns 1–2 show the results when the dealer sells interest rate protection (receives fixed), while Columns 3–4 show the results when the dealer buys protection (pays fixed). The sample covers every USD-denominated spot vanilla interest rate swap by non-US-based counterparties (excluding entities with unclassified location), which was reported to DTCC between December 1, 2014 and February 19, 2016. All specifications include time, buyer ID, and seller ID fixed effects. We report t-statistics calculated using clustered standard errors (by quarter and dealer ID) in parentheses. *, **, *** denote significance at 1%, 5%, and 10% confidence level, respectively.

	Dealer receiving fixed		Dealer paying fixed	
	(1)	(2)	(3)	(4)
Non-CCP dummy	6.918***	7.767**	1.332	-1.032
	(3.20)	(2.33)	(1.37)	(-0.52)
Log-notional	0.406*	0.183	0.207	-0.171
	(1.80)	(0.53)	(0.75)	(-0.45)
Maturity	0.029	0.025	0.031	0.160***
	(0.80)	(0.43)	(0.42)	(2.95)
Credit rating of buyer				-2.149
				(-1.31)
Credit rating of seller		1.413		
		(1.16)		
CR of dealer (buyer)				-0.192
				(-0.28)
CR of dealer (seller)		0.325		
		(0.63)		
LR of dealer (buyer)				0.197
				(0.70)
LR of dealer (seller)		0.271		
		(1.25)		
Day, Buyer ID, Seller ID FE	Yes	Yes	Yes	Yes
$\overline{R}^2$	0.153	0.169	0.258	0.355
Obs	13095	7922	10092	4229