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Centralized trading, transparency and interest rate swap market liquidity: evidence from the implementation of the Dodd-Frank Act

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Centralized trading, transparency and interest rate swap market liquidity: evidence from the implementation of the Dodd-Frank Act

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Abstract

We use proprietary transaction data on interest rate swaps to assess the impact of centralized trading, as mandated by Dodd-Frank, on market quality. We show that it has led to activity increasing and liquidity improving, with the largest improvements for contracts most affected by the mandate. Associated reductions in execution costs are economically significant eg daily end-user costs of trading USD relative to EUR mandated contracts drop by \$3 million–\$4 million. We show that requiring centralized trading in the United States caused swap markets to fragment geographically and give evidence which suggests that fragmentation is due to dealers trying to maintain market power.

Key words: Swap Execution Facilities, transparency, liquidity.

JEL classification: G10, G12, G14.

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1 Introduction

This paper is a study of how recent regulatory changes to Over-the-Counter (OTC) derivative markets have altered the quality of those markets. In particular, we examine how implementation of the centralized trading mandate of the Dodd-Frank act has impacted liquidity and trading patterns in interest rate swap (hereafter 'swap') markets, the world's largest OTC derivative market (BIS (2014)).

Prior to the implementation of Dodd-Frank, swap trading was largely decentralized and opaque. There was no central source for trade information and no liquidity hub that published pre-trade information on quotes and sizes. Therefore, buyers and sellers bore pecuniary and time costs when searching for quotes and counterparties (see Duffie et al. (2005) and Duffie (2012)). The opaque nature of the market and imperfect competition among swap dealers may also have allowed the largest swap dealers to exploit other traders (see Kyle (1985) and Vayanos and Wang (2012)).

A key change to swap trading, as a result of Dodd-Frank, was the introduction of Swap Execution Facilities (SEFs).[1] These are multi-lateral trading venues, featuring an open limit order book (LOB) as well as a request for quote (RFQ) functionality whereby customers can electronically solicit quotes from multiple dealers simultaneously. Thus, SEFs represent a consolidated liquidity pool via which investors can see firm, quoted swap rates on a continuous basis and as such they dramatically alter the traditional, voice-based, bilateral mode of trading in OTC derivatives markets.

SEF trading has been available since early October 2013, and since February 2014 all trades in eligible swap contracts, that involve US persons, must take place

[1] Dodd-Frank also mandated central clearing of swap trades as well as post-trade disclosure of swap trade details. The clearing mandate came into effect on March 11, 2013 and the trade reporting mandate came into effect on December 31, 2012.

on a SEF. The SEF mandate implementation was followed by a debate amongst regulators about the efficacy of the reform and its impact on liquidity and trading relations (see Giancarlo (2015), Massad (2016), Powell (2016)). In addition, similar rules are currently on the drawing board in the European Union, as part of the Markets In Financial Instruments Regulation (MiFIR), and are expected to be rolled out by 2018.

Our goal is to test whether this regulatory innovation has improved or damaged swap market liquidity. For our analysis we use proprietary data from the London Clearing House (LCH) between January 2013 and September 2014, supplemented with public data from the Depository Trust & Clearing Corporation (DTCC). Both sources contain information on executed swap transactions. The LCH data, in addition to the usual trade variables, contains counterparty information from which we can infer traders' geographic locations (e.g. US- versus non-US-based entities) and trader type (e.g. dealer versus client). The data also tell us whether a trade was executed on a SEF. We employ a difference-in-differences technique to isolate the effects of the introduction of SEF trading on liquidity. Liquidity here is measured using the dispersion of execution prices around a benchmark, as in Jankowitsch et al. (2011), or Amihud's price impact measure (Amihud (2002)). The treatment group of assets in our difference-in-differences tests is the set of USD swaps that were required to trade on a SEF after February 2014. Our control groups are either the USD swaps that were not captured by the SEF trading mandate or the EUR swaps that were mandated, but which are mostly traded by non-US persons who, in turn, are not captured by the SEF trading requirement.

We show that the introduction of SEF trading was associated with a statistically and economically significant improvement in liquidity and trading activity, particularly for those swaps where SEFs are most heavily used. For example, relative to EUR mandated swaps, execution costs for USD mandated swaps drop by about \$3 - \$4 million *daily* for market end-users (i.e. non-dealers). This results from an absolute reduction in execution costs for both USD and EUR mandated contracts. In particular, total execution costs for end-users are reduced by about \$7 - \$13 million daily for USD mandated swaps and by \$3-\$9 million daily for EUR mandated contracts, after the introduction of SEF trading. Overall, our findings suggest that greater penetration of multi-lateral transparent venues improves trading conditions. They also suggest that the introduction of SEFs addressed some of the market imperfections observed in traditional OTC markets. As a result of the more centralized and more pre-trade transparent swap trading via SEFs, quote competition strengthened, participation increased and liquidity improved.[2]

We then examine if the SEF trade mandate has brought about any changes in the geography of trading. The mandate only captures US persons, meaning that, for every other market participant, trading on-SEF is optional. Thus, to the extent that a non-US person might want to trade off-SEF, they would need to select another non-US entity as a counterparty. Such a desire to trade off-SEF may, therefore, geographically fragment swap markets. The possibility of a geographical fracture in swap markets, and an associated drop in market liquidity, has been a feature of the policy debate since the implementation of the SEF trade mandate.[3]

We find that, after the introduction of SEFs, the percentage of trading volume between US and non-US domiciled traders in EUR swaps declined markedly and abruptly from a daily average of 20% to 5%, while no changes were observed for

[2]According to data from the National Futures Association (NFA), in practice there is limited usage of the SEF LOB functionality so any increase in pre-trade transparency is mainly driven by the RFQ mechanism. The trading mandate also aimed to increase post-trade transparency by requiring SEFs to publish daily trading activity on their websites. We describe SEF characteristics in detail in Section 3.

[3]See, for example, industry reports such as ISDA (2014a), ISDA (2014b), as well as a recent US Commodity Futures Trading Commission (CFTC) white paper (Giancarlo (2015)).

USD swaps. Further, we show that the observed decline in trans-Atlantic volume for EUR contracts, was almost entirely driven by swap dealers with trading desks in multiple locations, migrating the bulk of their inter-dealer activity to their non-US (primarily European) branches.[4] We do not observe any similar pattern for trades that involve end-users.

This suggests that there are costs, pecuniary or otherwise, to trading on SEFs which dealers seek to avoid. For example, dealers in EUR denominated swaps may wish to move their trading activity from their US desks to European desks if this enables them to trade off-SEFs and retain a degree of power over who they trade with. This power could allow them to exclude new entrants from the inter-dealer EUR swap market which, in turn, would preclude new entrants from trading effectively in the client market.[5] Thus, the observed geographic fragmentation might be a result of dealers attempting to maintain entry barriers to (EUR) swap trading.[6]

This raises the question whether the migration of inter-dealer volume to non-US branches has in itself impaired market liquidity. This concern has ben expressed

[4]For related press coverage, see also 'Big US banks make swaps a foreign affair' in the Wall St Journal (`http://www.wsj.com/articles/SB10001424052702304788404579520302570888332`).

[5]This would not be feasible for USD swaps as the inter-dealer market is well established, geographically, in the US, while the bulk of EUR swap trading already happens in Europe.

[6]In fact, in November 2013, the CFTC published guidelines pertaining to SEFs (Commodity Futures Trading Commission (2013)), which, amongst other things, gives examples of SEF "enablement mechanisms" which can be used to restrict the ability of some market participants to interact with a SEF's trading systems. For example, one such mechanism (labeled "counterparty filter"), might "preven[t] a market participant from interacting or trading with, or viewing the bids and offers (firm or indicative) displayed by any other market participant on that SEF, whether by means of any condition or restriction on its ability or authority to display a quote to any other market participant or to respond to any quote issued by any other market participant on that SEF, or otherwise". Such a mechanism could be used by incumbent dealers to deny access to the interdealer market to a potential entrant. In its guidelines, the CFTC deemed such activities inconsistent with the requirement for impartial access on SEFs.

in a number of industry reports and in the press.[7] Our analysis shows that this migration has not had any incremental negative effect on trading costs. However, our results do suggest that it has likely prevented EUR swap liquidity from sharing the improvement documented in the USD segment of the market.

Overall, our results show that the increased transparency and lower entry barriers that SEFs brought about have significantly improved trading conditions for swaps, especially for those instruments that were forced to trade upon them. However, the uneven application of regulation of this global market across different regions has caused trading to fracture along geographical lines, meaning that the liquidity benefits of increased centralization and competition are not being fully realized.

The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 sets out the regulatory changes that affected swap markets as a result of Dodd-Frank and gives a detailed description of SEFs. Section 4 describes our data sources and presents a set of summary statistics. Section 5 presents the difference-in-differences tests of the impact of centralized trading on market activity and liquidity. Section 6 describes the changes in the geography of swap trading and Section 7 concludes.

2 Literature Review

Our work is related to a sizeable literature on the relationship between execution costs and transparency in various market settings. On the theoretical side, the most closely related paper is Duffie et al. (2005) who formally show that "bid-ask

[7] See for example ISDA (2014a) and ISDA (2014b) for an industry perspective as well as press coverage in the Financial Times such as 'CFTC Calls for International Help on Derivatives Oversight' (`http://www.ft.com/cms/s/0/3aeabbb0-6b63-11e4-9337-00144feabdc0.html`) and 'US swaps trading rules have split market' (`http://www.ft.com/cms/s/0/58251f84-82b8-11e3-8119-00144feab7de.html`).

spreads are lower if investors can more easily find other investors or have easier access to multiple market-makers".[8] Another relevant study is Hendershott and Madhavan (2015) who examine the efficacy of electronic venues at facilitating trading in OTC markets. These authors show that a periodic one-sided electronic auction mechanism can be a viable source of liquidity. Interestingly, this mechanism has some similarities to the SEF RFQ functionality in that it encourages dealer competition without disseminating trading intentions and dealer quotes to all market participants. This results in better prices while limiting information leakages. Theory predictions in Pagano and Roell (1996) also support the view that more transparency enhances liquidity. Vayanos and Wang (2012) survey the literature and explain how illiquidity is related to various market imperfections. They show that participation costs, imperfect competition and search frictions all have a detrimental effect on liquidity.

The result that increased pre-trade transparency improves liquidity chimes with those from work on other asset classes.[9] For example, Boehmer et al. (2005) show that when the NYSE allowed traders who were not located on the exchange floor to see the contents of the limit order book, this resulted in a significant improvement in liquidity. Harris and Piwowar (2006) argue that the fact that smaller corporate bond trades are more costly to execute than large trades is due to large trades being done by large institutions with clear views of the market while small traders suffer a lack of transparency and thus greater costs. Green et al. (2007) study municipal bond markets and find that dealers earn lower average markups on larger trades even though they bear higher risk. The authors interpret this as evidence of dealer

[8] Similarly, Yin (2005) shows that, in the presence of costs for searching for better prices, expected spreads are smaller in centralized markets. These markets are preferred by liquidity traders, while dealers prefer fragmented markets.

[9] It is also in line with the experimental results in Flood et al. (1999), who demonstrate that opacity, through its effect on search costs, reduces liquidity (although it causes price discovery to improve).

market power that results from market opacity. They proceed to show how dealer market power increases execution costs and also that it is positively related to the length of intermediation chains. Goldstein et al. (2007), Edwards et al. (2007) and Bessembinder et al. (2006) show that introducing post-trade transparency to US corporate bond markets had, on balance, a positive effect on liquidity (exceptions were found for very thinly-traded bonds and for the largest trades). Evidence that links transparency with liquidity in other markets can also be found in Naik et al. (1999) and Boehmer et al. (2005). Foucault et al. (2010) offer a survey of the theoretical and empirical literature on market transparency.

Finally, our work is related to a number of more recent studies focusing on OTC derivatives markets and the impact of recent regulatory developments. Fulop and Lescourret (2015) study the impact on liquidity of the standardization of contracts (in 2009) and the reporting of aggregate weekly post-trade data (in 2008) in the single-name CDS market. They find that the standardization of CDS contracts improved liquidity across the market, while the post-trade data disclosure improved the liquidity only for a subset of CDS contracts. Loon and Zhong (2014) and Loon and Zhong (2015) also study the effects of Dodd-Frank, although they concentrate on the two other key provisions of the Act, namely centralized clearing and post-trade reporting.[10] Employing data from the CDS market, they show that the introduction of a central counterparty to CDS trades reduces counterparty credit risk and, through its effect on post-trade transparency, improves liquidity. They also show that an increase in post-trade transparency brought about by post-trade reporting also contributed to improvements in liquidity. Our paper focuses instead on the impact of pre-trade transparency as related to the third pillar of the Dodd-Frank OTC derivatives regulation, i.e. the mandate for centralized trading. Our

[10] For an overview of centralized clearing in credit derivatives, see Acharya et al. (2009).

study also focuses on the IRS market which is substantially larger in terms of notional amounts outstanding than the CDS market.

3 Policy Context and Institutional Details

3.1 OTC derivatives and the Dodd-Frank Act

A major pillar of the US Wall Street Reform and Consumer Protection Act (the "Dodd-Frank Act") concerns OTC derivatives markets. In particular, owing to concerns that insufficient collateralization and opacity in these markets contributed to systemic risk during the crisis, Title VII of the Act implemented a series of reforms aimed at mitigating counterparty risk and improving pre- and post-trade transparency in swaps markets. As such, it mandates centralized clearing for eligible contracts, it requires real-time reporting and public dissemination of transactions and also requires that eligible contracts should be traded on SEFs, a form of multilateral electronic trading venue. Because of its characteristics (described in detail in the next section), SEF trading brings about a marked increase in the level of *pre-trade* transparency for the affected swap contracts.

The Dodd-Frank trading mandate was implemented by the CFTC in two phases. In the first, which took effect on October 2, 2013, SEF trading became available for OTC derivatives on a voluntary basis. This meant that, as of that date, the newly authorized trading venues had to comply with a number of principles and requirements, including for instance the obligation to operate a limit order book and to automatically disseminate requests for quotes to multiple dealers.[11] In the second phase, specific contracts were explicitly required to be executed on SEFs. The mandate captured a wide range of interest rate swap (IRS) contracts of various currencies and maturities as well as several credit default swap (CDS) indices. The determination of the mandated contracts was (and still is) primarily SEF-driven (through the Made Available to Trade (MAT) procedure). A SEF can submit a determination that a swap is available for trade to the CFTC, which then reviews the submission. Once a swap is certified as available to trade, all other SEFs that offer this swap for trading must do so in accordance with the requirements of the trade mandate. The criteria for MAT determination include the trading volume of the swap and the frequency of transactions. Table 1 shows the mandated maturities along with the mandate date for the plain vanilla USD- and EUR-denominated IRS contracts which we use in our analysis. Most maturities were mandated on February 15 2014 with a couple more maturities following suit a few days later on the 26th.

The SEF trading mandate only captures "US persons" with the definition of a US person being relatively broad.[12] Importantly, the mandate affects the trades of US persons regardless of who their counterparty is. In other words, if a US

[11] This does not mean that there were no electronic venues in operation or that no swaps were being traded on limit order books or other multilateral trading platforms before October 2, 2013. It only means that after this date, any venue that was officially recognized as a SEF had to comply with the specific CFTC minimum requirements mentioned above. Unfortunately, we have no data on the methods of execution prior to October 2, 2103. Nevertheless, if swaps were already being traded on pre-trade transparent electronic platforms before this date, this should bias us against finding any differences in market conditions when making a "before versus after" comparison. Our analysis shows that the differences were actually substantial.

[12] Apart from US-registered swap dealers and major participants, the definition of a US person also includes foreign entities that carry guarantees from a US person (e.g. the foreign branch of a US dealer) and also any entities with personnel on US soil which is substantially involved in arranging, negotiating or executing a transaction. According to market reports this created initially some uncertainty as to who is captured. See for example: `http://www.risk.net/risk-magazine/news/2256600/broader-us-person-definition-could-cause-clearing-avalanche-participants-warn`

person is to trade a mandated contract with a non-US person, the trade has to be executed on a SEF.

3.2 Swap Execution Facility (SEF) Characteristics

SEFs are electronic trading platforms where, according to the CFTC, "multiple participants have the ability to execute swaps by accepting bids and offers made by multiple participants in the platform". In practice, SEFs have two different functionalities to facilitate this. The first is a fully fledged central limit order book which allows any market participant to supply liquidity by posting bids and offers.[13] Theoretically, this functionality allows end-users to bypass dealers altogether in concluding a trade, assuming of course that the order book has sufficient liquidity.

The second functionality is a modification of the existing request-for-quote (RFQ) dealer-centric model. The innovation, relative to standard single-dealer platforms, is that a client's request for a quote is disseminated simultaneously and instantly to multiple dealers instead of just one. This enables the client to easily compare prices across dealers and thus promotes competition for client order flow among dealers. The law required that a RFQ be communicated to no less than two market participants during a phase-in period until October 2014 and, subsequent to that period, to no less than three market participants. Upon transmission of the request for quote, the dealers may respond by posting their quotes to the client.[14] Importantly, dealers cannot see each others' quotes nor do they know how

[13]For swaps that are subject to the trade mandate, SEF regulation also requires that broker-dealers, who have the ability to execute against a customer's order or execute two customers against each other, be subject to a 15-second timing delay between the entry of the two orders on the LOB. This is intended to limit broker-dealer internalization of trades and to incentivize competition between market participants.

[14]It is worth noting that CFTC did not impose any requirement that the identity of the RFQ requester be disclosed. This was due to concerns expressed by market participants that the disclosure of the RFQ requester identity would cause information leakages about future trading intentions. See Foucault et al. (2007) and Nolte et al. (2015) for a discussion on the implications of the disclosure of counterparty identities.

many and which other dealers have received the request. In addition, the market participants responding to the RFQ cannot be affiliated with the RFQ requester and may not be affiliated with each other. This arrangement makes it hard for dealers to collude and effectively renders the bidding process a first-price, sealed bid auction.

The two trading functionalities are designed to operate in conjunction for swaps that are subject to the trade execution mandate. This means that a SEF must provide a RFQ requester with any resting bid or offer on the SEF's order book alongside any quotes received by the dealers from whom quotes have been requested. The requester retains the discretion to execute either against the resting quotes on the LOB or against the RFQ responses.[15] Upon execution of a transaction on a SEF's LOB or RFQ system, the SEF can establish a short time period for a work-up session open to all market participants. That is all market participants can trade an additional quantity of the same swap at the same price as the initial trade. The SEF's trading protocol can provide the counterparties who initiated the first trade execution priority in the work-up session. Duffie and Zhu (2015) show that work-up protocols can enhance price discovery and liquidity.

Overall, SEFs change the microstructure of the market in two important ways. First, they increase pre-trade transparency in the IRS and CDS markets by allowing market participants to observe prices quoted by dealers much more easily. Previously, if an end-user wanted to shop around for prices she would have to sequentially contact multiple dealers. This was both expensive and time consuming. Second, SEFs increase competition between swap liquidity suppliers. SEFs make comparison of dealer quotes much more straightforward, they allow new entrants

[15] Any trades of swap contracts that are not subject to the mandate can still be executed on a SEF and the SEF must offer an order book. However, the SEF is also free to offer any other method of execution (including bilateral trading and voice-based systems) for these trades.

to the swap dealing business to start supplying liquidity on LOBs and they allow end-users to trade directly with each other and to completely bypass dealers. While, in practice, most of the liquidity provision is still being done by traditional dealers, SEFs have eroded their market power and increased competitive pressures.

4 Data and Summary Statistics

4.1 Swap Transaction Data

In our analysis we use transaction data for USD and EUR denominated vanilla spot interest rate swaps, which we obtain from the LCH and the DTCC.

LCH clears approximately 50% of the global interest rate swap market and more than 90% of the overall cleared interest rate swaps through the SwapClear clearing platform. Its services are used by almost 100 financial institutions from over 30 countries, including all major dealers. We obtain the reports of all new trades that were cleared by LCH between January 1, 2013 and September 15, 2014.

Each LCH report contains information on the date of trade, effective trade, maturity date, notional, swap rate, and other contract characteristics. In addition, a report includes the identities of the counterparties, which allows us to categorize trades by type of counterparty (dealer vs. non-dealer) and location (US, EU etc). Since April 2014 LCH reports also contain information on whether a transaction is executed on a trading venue, the name of the venue, as well as whether the venue is authorized as a SEF.

We apply a number of filters to clean these data. First, we keep only spot starting swaps, which we do by removing any reports whose effective date is more than 2 business days from the trade date. Next, we remove duplicate reports. Duplicate reports exist because for every transaction that is centrally cleared, the clearing house produces one report per counterparty. We also remove any portfolio or compression trades as they are not price-forming.[16] Finally, to remove any inaccurate or false reports we keep only trades where the percentage difference between the reported swap rate and Bloomberg's end-of-day rate for the same currency and maturity is less than 5% in absolute value.

Although LCH is the global leader in clearing interest rate swaps, there are other clearing houses that offer competing services, for example the Chicago Mercantile Exchange (CME). To ensure that our results are representative of the whole clearing space, we complement the LCH data with data from the DTCC, a trade repository (TR) operator. As part of the Dodd-Frank Act, the CFTC required all US and certain types of non-US market participants to submit trade reports to swap trade repositories, which in turn make these data available to the public in real-time.[17] The DTTC was the first to operate a TR on December 31, 2012. We extract all transactions that were reported to the DTCC between January 1, 2013 and September 15, 2014. DTCC reports contain information on many contract characteristics, including whether a trade is centrally cleared or executed on a SEF. Similar to the LCH data, we select centrally cleared USD and EUR denominated vanilla spot interest rate swaps. In addition, we remove any duplicates, cancellation reports, and any swaps with additional terms that affect the swap's price. We also remove extreme prices and misreports by applying the same rules as used for the LCH data. The final step in our data cleaning methodology is the removal of any trades that were reported to both LCH and DTCC. To remove

[16] Compression trades are used in order to reduce the total notional amounts outstanding of the participating institutions, while leaving their net notional amounts unchanged. The purpose of this is to reduce the amount of counterparty risk (which is a function of gross notional) while maintaining the same level of exposure to market risk.

[17] For more details see the CFTC's "Interpretive Guidance and Policy Statement Regarding Compliance with Certain Swap Regulations" at `http://www.cftc.gov/idc/groups/public/@newsroom/documents/file/crossborder_factsheet_final.pdf`.

these duplicate reports we apply an algorithm that matches LCH and DTCC reports based on trade date, effective trade, maturity date, notional, swap rate, and other contract characteristics that are common in both data sets.

After filtering the data, we are left with a sample of 628,896 trade reports which account for a total $58.17 trillion in traded notional over our sample period. In Figure 1 we show the time series of trading volume by currency. This figure illustrates the sheer size of the swap market with volumes hovering around $70-80 billion for each currency on a daily basis. We can also see that total volume is roughly equally split between USD and EUR denominated swaps.

A unique feature of the LCH reports is that they contain information on the identities of the counterparties. Specifically, for every trade that is centrally cleared by LCH we can see the Business Identifier Code (BIC) code of the counterparties.[18] The BIC allows us to identify the dealers, their branches and their associated jurisdictions. OTC derivatives dealers are primarily large international financial institutions that facilitate trading between end users. We classify as dealers the top 16 banks by volume in our sample, while any other counterparty is classified as a client.[19]

In Figure 2 we present the shares of volume by type of counterparty. The majority of trades are between dealers, which is consistent with the commonly held view that a small number of dealers dominates the OTC swap market. Dealer-to-client trades account for about one-third of the market in both currencies. One difference between the two currencies is that the share of client-to-client trading

[18] BIC is a unique identification code for financial institutions approved by the International Organization for Standardization (ISO). It has typically 8 characters made up of (i) 4 letters that identify the bank, (ii) 2 letters that identify the country, and (iii) 2 letters or digits that identify the city.

[19] 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`

activity for USD-denominated swaps is twice as large as that in EUR-denominated swaps.

With regard to location, we use the BIC to decompose trading activity into (i) trades between US financial institutions, (ii) trades between US and non-US financial institutions, and (iii) trades between non-US financial institutions. Figure 3 presents this decomposition. About 50% of trading in USD-denominated swaps involves a US and a non-US counterparty, 30% two US counterparties, and 20% two non-US counterparties. For EUR-denominated swaps, the US to non-US trading activity makes up only 14% of the sample, while the vast majority of trades, about 80%, are between non-US counterparties.

Using the DTCC data, we plot in Figure 4 the time series of on-SEF trading from January 1, 2013 to September 15, 2014. We observe that after October 2, 2013, the date when SEF trading was introduced, the majority of USD-denominated swaps reported to DTCC are executed on swap execution facilities. The fraction of SEF trading for these swaps (the blue line) increases steadily, from about 60% in October 2013 to over 80% in September 2014. On the other hand, SEF trading in EUR-denominated swaps is less pronounced, with the fraction of SEF trading (the red dotted line) hovering between 20% and 40%.

Figure 4 demonstrates that the CFTC does not have the power to enforce the US trading mandate in markets that are dominated by non-US counterparties, for example the EUR-denominated swap market (see Figure 3). This observation motivates the empirical strategy employed later in the paper.

5 SEF Trading and Market Quality

5.1 Liquidity Variables

Our choice of liquidity variables is driven by data availability and the OTC nature of the IRS market. The main limitations we face are the lack of reliable bid and ask quotes and the fact that our trade reports are not time-stamped. As a result, we cannot construct a direct measure of effective spreads or any liquidity metric that relies on transaction sequencing. Instead, we use metrics that require only executed trades.

We use two price dispersion measures to proxy for execution costs. The first is the price dispersion proposed by Jankowitsch et al. (2011). This is defined as:

$$DispJNS_{i,t} = \sqrt{\sum_{k=1}^{N_{i,t}} \frac{Vlm_{k,i,t}}{Vlm_{i,t}} \left(\frac{P_{k,i,t} - m_{i,t}}{m_{i,t}} \right)^2} \tag{1}$$

where $m_{i,t}$ is the end-of-day t mid-quote of contract i, as reported by Bloomberg, $Vlm_{k,i,t}$ is the volume of transaction k and $Vlm_{i,t} = \sum_k Vlm_{k,i,t}$ is the total volume for contract i on day t. Jankowitsch et al. (2011) derive this measure from a market microstructure model where it is shown to capture inventory and search costs, making it a good candidate for measuring liquidity in OTC markets. Low dispersion of prices around the Bloomberg benchmark indicates low trading costs and high liquidity, and vice versa.

The use of end-of-day Bloomberg quotes as a benchmark of a contract's *fair value* might be problematic in days of high intraday volatility. For example, the value of a contract might be very different before and after a macroeconomic announcement. To control for this possibility we employ a variation of the Jankowitsch et al. (2011) price dispersion where we use the average execution price on a day as the price benchmark. More formally:

$$DispVW_{i,t} = \sqrt{\sum_{k=1}^{N_{i,t}} \frac{Vlm_{k,i,t}}{Vlm_{i,t}} \left(\frac{P_{k,i,t} - \bar{P}_{i,t}}{\bar{P}_{i,t}} \right)^2} \tag{2}$$

where $N_{i,t}$ is the total number of trades executed for contract i on day t, $P_{k,i,t}$ is the execution price of transaction k, $\bar{P}_{i,t}$ is the average execution price on contract i and day t, and we require at least four intraday observations to determine the average execution price. Both dispersion metrics are comparable across contracts of different currencies and maturities as they are percentage deviations from a price benchmark.

The last liquidity variable we use is the Amihud (2002) price impact, defined for contract i on day t as:

$$Amihud_{i,t} = \frac{1}{T} \sum_{j=0}^{T-1} \frac{|R_{i,t-j}|}{Vlm_{i,t-j}} \tag{3}$$

where we take $T = 40$ and $Vlm_{i,t}$ is the total volume traded for contract i on day t, expressed in \$ trillion. All of these liquidity measures have been used before in the context of OTC derivatives markets and are shown to strongly relate to other conventional liquidity proxies, see for example the evidence in Goyenko et al. (2009), Friewald et al. (2012), Friewald et al. (2014), Loon and Zhong (2014), and Loon and Zhong (2015) among others.

5.2 Panel diff-in-diff specifications

To assess the impact of SEF trading on market liquidity and activity, we estimate two panel specifications that implement difference-in-differences tests. The idea is to see if the impact of SEF trading on a treatment group of IRS contracts causes their liquidity to diverge from that of a control group after our event dates. As event dates we take the 2nd of October 2013 when SEF trading became available (and trades could be executed on SEFs on a voluntary basis) and the CFTC mandate effective dates shown in Table 1. On these dates (which vary across contract maturities) it became mandatory for US persons to trade the specific maturities on SEFs.[20] Table 2 summarizes the main variables used in the difference-in-differences models that follow.

Test 1: USD vs. EUR mandated contracts

For our first diff-in-diff test we use the mandated USD-denominated contracts as a treatment group and the mandated EUR-denominated contracts as a control group. The USD segment of the IRS market has a substantially higher proportion of U.S. participants who are captured by the CFTC mandate. The EUR contracts, however, may be mandated but they are mainly traded by non-US persons who are not required to trade on a SEF (see Figure 3). Thus, if transparency improves liquidity, we would expect the liquidity of USD contracts to improve relative to that of EUR contracts.[21] An advantage of using the mandated EUR-denominated contracts as a control group is that both the treatment and control groups have similar liquidity profiles, which implies that our results are not subject to selection bias. On the other hand, liquidity and activity in the EUR segment of the market might be driven by different fundamentals. We control for this possibility by including a number of currency specific control variables in our specifications.

[20] These event dates are after the implementation of the reporting mandate on December 31, 2012 and the clearing mandate on March 11, 2013. Nevertheless, the clearing mandate implementation occurs during our pre-event sample period which starts on January 2, 2013. For this reason, we also do our analysis using data only after March 11, 2013. Since the results are essentially the same as the ones obtained when using the full data, they are not reported here.

[21] Of course, to the extent that SEFs are also used by participants in EUR mandated contacts, even to a lower degree, we would expect their liquidity to improve too, albeit by a smaller amount.

We implement this test by estimating the following panel specification:

$$L_{it} = \alpha + \beta_1 Date_t^{(1)} + \beta_2 Curr_i Date_t^{(1)} + \beta_3 Date_t^{(2)} + \beta_4 Curr_i Date_t^{(2)} + \gamma' X_t + u_i + \epsilon_{it} \tag{4}$$

where i indexes the set of swap contracts (defined by maturity and currency) and t denotes days. L_{it} is a liquidity or market activity variable. These are the dispersion and Amihud variables defined in equations (2) to (3) whereas our activity variables include daily volume traded, the daily number of trades executed and the number of unique market participants active on a given day. $Date_t^{(j)}$, $j = 1, 2$ are dummies for the two event dates equalling one after the respective events and zero otherwise, $Curr_i$ is a currency dummy that is equal to one for USD contracts and zero for EUR contracts and X_t is a vector of controls. The control variables include stock market returns, stock index implied volatilities as proxies for overall market uncertainty, overnight unsecured borrowing rate spreads for both markets as proxies for dealer funding costs and yield curve slopes intended to capture differences in fundamentals between the USD and EUR market segments. This specification explicitly disentangles liquidity/activity in the two currency groups as well as any changes in liquidity after the two events. The coefficients β_1 and β_3 capture any effects that are common to both market segments and coefficients β_2 and β_4 capture incremental effects that are particular to the USD market segment. We estimate the model using currency and maturity fixed effects and cluster the standard errors by both maturity and currency.

Table 3 shows the results of this estimation. The models are estimated with and without the control variables, although there is little difference in the key coefficients across those two specifications. A first result to note is that after SEF trading became available on 2 October 2013 ($Date^{(1)}$ dummy) there is an improvement in liquidity for both market segments as the significantly negative coefficients on $Date^{(1)}$ and the insignificant interaction terms indicate. On the contrary, following the SEF mandate there is a clear differential effect between the USD and EUR segments of the market with the USD contracts showing a significant further liquidity improvement relative to the EUR contracts.

These effects are economically very significant. For example, the coefficients for the $Curr \times Date^{(1)}$ and $Curr \times Date^{(2)}$ interaction terms in the dispersion specifications suggest that the marginal reduction in execution costs of the USD mandated versus the EUR mandated contracts is in the order of 12% to 16% of previous dispersion levels. This reduction in execution costs amounts to roughly $3-$4 million *daily* for market end-users. The total effect for USD mandated contracts is yet bigger with a drop in execution costs by about 22% to 27% of previous dispersion levels, which amounts to roughly $7-$13 million daily for end-users. The effect on the EUR contracts is also substantial, despite the fact that fewer participants are captured by the mandate. The reduction in execution costs is about 10% to 12% or $3-$9 million daily. These calculations are based on the standard pricing formula of a fixed-to-floating swap and measure the present value of the savings that accrue to end-users as a result of reduced execution costs associated with a contract's fixed future payments.[22]

Regarding the activity variables, the results suggest that there was a reduction in activity for EUR contracts and a respective increase in USD contracts mainly after SEF trading became available. It is interesting here that although activity

[22] More specifically, we calculate the reduction in execution costs for all market participants as: $\sum_i \beta_i \times Vlm \times \bar{P} \times Maturity$ where β_i are the estimated coefficients from model (5), Vlm is the average daily volume of USD mandated contracts ($75 billion), $\bar{P}$ is their average volume-weighted price (1.7%) and $Maturity$ is their average volume-weighted maturity (7 years). In doing this calculation we are assuming a zero risk-free rate which is realistic for the time period that we consider. We multiply further with the average fraction of dealer-to-client volume (33%) to estimate the reduction in execution costs for the market end-users.

in EUR mandated contracts declined, liquidity actually improved, presumably because the market became more transparent. We do not observe any significant difference in trading activity between the USD and EUR contracts after the second event (February 2015). Another noteworthy effect is that after both events, the number of parties trading in USD markets rose significantly relative to the number of traders in EUR markets. Thus breadth of participation in USD markets rose.

In all of these estimations, coefficients on the control variables are largely insignificant; the only consistently signed and significant coefficient is that on the VIX, which indicates that execution costs and activity rise in more volatile times, consistent with microstructure theory.

Test 2: USD mandated vs. USD non-mandated contracts

For the second diff-in-diff test we concentrate exclusively on USD contracts and use the mandated maturities as a treatment group and non-mandated USD swaps as the control group.[23] This test has the advantage of comparing contracts whose prices are driven by the same set of fundamentals.

We implement this test by estimating the following panel specification:

$$L_{it} = \alpha + \beta_1 Date_t^{(1)} + \beta_2 MAT_i Date_t^{(1)} + \beta_3 Date_t^{(2)} + \beta_4 MAT_i Date_t^{(2)} + \gamma' X_t + u_i + \epsilon_{it} \tag{5}$$

where now i denotes maturities and t denotes days. The key right-hand side variables used are the same as above with the only difference being that we now have a dummy variable (MAT_i) indicating whether a given contract maturity has been mandated by the CFTC. Also, as we are only dealing with USD contracts in this estimation, we shrink the control variable set to remove data from European

[23]The mandated maturities are: 2Y, 3Y, 5Y, 7Y, 10Y, 12Y, 15Y, 20Y and 30Y. The non-mandated maturities are: 1Y, 8Y, 9Y and 25Y.

equity and fixed income markets. We estimate this model using maturity fixed effects.

Table 4 shows the results of these estimations, again both with and without control variables. The results are similar to those obtained in the previous analysis. In particular, there is clear evidence of liquidity improvements for both mandated and non-mandated contracts after SEF trading became available on 2 October 2013. The improvement in liquidity is partially reversed for non-mandated contracts after February 2014 but remains intact for mandated ones. Overall, liquidity rises for both mandated and non-mandated USD contracts with the increase being significantly greater for the former.

Thus, it appears that the liquidity improvements in the mandated contracts spilled over - to some extent - to non-mandated contracts. This is likely because market participants also chose to trade non-mandated contracts on SEFs as soon as the functionality became available, and presumably also because more transparency for some quoted prices on the maturity curve gives market participants a better idea of what a fair quote is for other maturities. As far as activity and participation are concerned, again, there are positive effects only for the mandated contracts which materialize after 2 October 2013.

5.3 SEF flag panel specifications

We next test directly how the fraction of SEF trading relates to our liquidity and market activity variables. For that, we utilize the DTCC segment of our data which contains a flag indicating whether a given trade was executed on a SEF or not.

Figure 4 shows the fraction of volume for USD and EUR-denominated plain vanilla IRS contracts that is traded on-SEF, as captured by the DTCC data. One can see that, for both currencies, volumes become positive after SEFs become available on 2 October 2013, but USD-denominated contracts generally have a higher degree of SEF trading than EUR-denominated ones. This is likely because a larger fraction of participants in the USD segment of the market are US persons who are captured by the SEF mandate.

To assess the impact of SEF trading on liquidity and market activity utilizing the SEF flag, we estimate the following panel specification for mandated USD and EUR-denominated contracts only, on a daily frequency:

$$L_{it} = \alpha + \beta_1 SEF_{it} + \beta_2 Date_t^{(1)} + \gamma' X_{it} + u_i + \epsilon_{it} \tag{6}$$

In this setup, L_{it} is the liquidity or market activity variable for contract i on day t. As before, we use the dispersion metrics and the Amihud measure defined in equations (1), (2) and (3) in order to capture liquidity. We also use total volume, number of trades and the number of unique participants to capture market activity. SEF_{it} is the percentage of SEF trading, $Date_t^{(1)}$ is a date dummy taking the value of 1 after the introduction of SEFs on 2 October 2013 and X_{it} is the same vector of controls used previously. We include the date dummy in the specification so as to see if the time and cross-sectional variation in SEF trading, conditional on SEF trading being available, has incremental explanatory power. Because it is possible that SEF trading is itself caused by market liquidity, we also estimate this model by IV, instrumenting SEF_{it} with its own lags.

Table 5 shows the results of this estimation. The coefficients on the percentage of SEF trading are significant throughout and consistent with the previous findings. A higher fraction of SEF trading is associated with increased levels of liquidity as captured by reduced values for both the dispersion metrics as well as the Amihud variable. Similarly, SEF trading is positive and statistically significant in the case of the activity variables: a higher fraction of SEF trading is associated with higher volumes, more trades and a larger number of market participants. Overall, these results suggest that SEF trading is associated with robust and measurable improvements in market quality.

6 Changes in the Geography of Trading

One concern among market participants and regulators, shortly after the SEF mandate took effect, was that it might lead to market fragmentation (ISDA (2014a)). Since the mandate to trade on a SEF only applied to US persons, it was conceivable that European, for example, counterparties who wished to avoid (for whatever reason) trading on a SEF, might do so by trading exclusively with other European counterparties. Indeed, some reports released after the implementation of the trade mandate suggested that the market was becoming fragmented and that this was causing market quality to deteriorate (e.g. Giancarlo (2015)).

In this section, we exploit our knowledge of counterparty identities in the LCH data and investigate this issue in detail. We first classify all market participants in the LCH data as US or non-US-based and calculate the percentage of trading volume that is executed between US and non-US counterparties (US-to-non-US).[24]

Figure 5 plots this percentage for USD and EUR-denominated contracts. It is evident that whereas no substantial effect takes place in USD-denominated contracts, after the introduction of SEF trading, there is a clear reduction in the fraction of US-to-non-US volume in EUR-denominated swaps, which drops from a daily average of 20% prior to the SEF introduction to an average of 5% after. More formally, Table 6 shows the results of time-series regressions of the fractions

[24]In practice, the majority of non-US activity is generated in Europe reflecting the fact that most non-US dealers are European entities.

of US-to-non-US volumes in USD and EUR contracts on the SEF introduction event dummy and a number of controls. The dummy coefficient is highly significant and negative for the EUR contracts whereas it is insignificant for the USD ones. We therefore confirm that the EUR segment of the swap market became substantially more fragmented following the introduction of SEF trading.

We conjecture that the observed difference between the two market segments is because of the much smaller proportion of US market participants in the EUR-denominated segment of the market: if a non-US counterparty wants to trade with another non-US counterparty and avoid executing on a SEF, they can do so much more easily for a EUR-denominated contract than for a USD-denominated one.

However, given the beneficial effects of SEF trading, this raises the question as to why any (and which) counterparties might want to avoid trading on SEFs. Figure 6 shows a breakdown of the fraction of US-to-non-US volume in the EUR-denominated contracts according to the type of counterparties. It is clear that the observed fragmentation is entirely driven by inter-dealer trading. Thus, it appears that it is the swap dealers who are trying to avoid using SEFs where possible. There is no observable fragmentation for EUR trades that involve at least one non-dealer. This might have been expected, as there is no incentive for customers to avoid trading on SEFs (given the liquidity improvements they offer).

The question that remains is why, at the time that SEF trading was introduced, cross-border activity by swap dealers dropped so clearly. One possibility is that inter-dealer trading between US-based and non-US-based dealers could genuinely have declined and could have been replaced by local (intra-US and intra-European) trading. Alternatively, inter-dealer trades between US and non-US firms could have been executed by the non-US branches of swap dealers who happen to have trading desks in multiple jurisdictions. For example, a trade between a US and a European dealer that was being executed by the US desk of the former, could now be executed by the European desk of the same dealer. In this case it would be registered as an intra-European trade and would not be subject to the SEF trade mandate. To see if this is the case, we plot in Figure 7 the fraction of inter-dealer trading in EUR contracts done by the US and non-US trading desks of only those swap dealers who have desks in multiple jurisdictions and who execute more than 10% of their swap volumes from a desk located in the United States. The figure shows that there is a sharp shift in inter-dealer activity from the US desks to the non-US ones. The fraction of non-US desk trading increases from a daily average of 75% prior to the introduction of SEFs, to an average of 95% after (with the corresponding fraction of US desk trading dropping from 25% to 5%). Additionally, Figure 8 shows that there is virtually no change in the amount of inter-dealer trading done exclusively by dealers who regularly trade the bulk (i.e. more than 90%) of their derivatives from their European desks. We interpret this as implying that the observed fragmentation is artificial in the sense that it is entirely driven by a change of the trading desk location of those dealers with desks and trading activity in multiple jurisdictions.

The preceding results are consistent with swap dealers strategically choosing the location of the desk executing a particular trade in order to avoid trading in a more transparent and competitive setting. A potential explanation for this lies in attempts to maintain market power. By shifting the location of the inter-dealer market to Europe and using European entities to execute, the SEF trading mandate and the associated CFTC impartial access requirements are avoided. This may give dealers control over who they trade with and how, which is turn would allow them to exclude any potential new competitors from inter-dealer trading. If, in turn, a potential competitor cannot access inter-dealer markets to manage inventory, their quotes are likely to be less tight and thus they are less likely to attract business in the customer market.

Motivated by the analysis above, we examine what geographical fragmentation in trading implies for market quality and activity in the EUR-denominated segment of the IRS market. For this, we estimate a panel specification similar to those estimated before:

$$L_{it} = \alpha + \beta_1 fragm_{it} + \beta_2 Date_t^{(1)} + \gamma' X_{it} + u_i + \epsilon_{it}, \qquad (7)$$

where L_{it} is a liquidity/activity variable of contract i on day t, $fragm$ is a measure of the degree of fragmentation defined as:

$$fragm \equiv 1 - \frac{\text{US-to-non-US Vlm}}{\text{Total Vlm}},$$

$Date^{(1)}$ is the dummy marking the introduction of SEF trading on 2 October 2013 and the controls are the same as before.

Table 7 shows the results of this estimation. Two key conclusions emerge from this Table. First, and consistent with anecdotal evidence, a higher degree of fragmentation is indeed associated with a slowdown in market activity as captured by the raw volume, number of trades and number of participants active. Second, fragmentation does not appear to have affected market liquidity.[25] A detrimental effect would require the estimated coefficient β_1 to be positive and significant. It is important to note that some of the concerns about fragmentation were explicitly about market depth decreasing and the potential price impact of trades increasing. The insignificant coefficient β_1 in the Amihud variable specification suggests that this concern is not backed up by the data. Given that the observed fragmentation

[25] We also estimate model (7) only using data after the introduction of SEF trading. The results are almost identical to the ones reported here and for this reason they are omitted.

is artificial, this is perhaps not surprising. However, if the fragmentation is caused by dealers attempting to maintain market power then, while liquidity might not have been damaged, it may not have improved as much as it could, if SEF trading in the EUR segment of the IRS market could not have been avoided by swap dealers.

7 Summary and Conclusion

One of the pillars of the G20 reform agenda for OTC derivatives markets is the requirement to migrate trading activity to more centralized venues, which facilitate greater transparency. In response, and as part of Dodd-Frank, US regulators have mandated that US persons should trade certain interest rate swap contracts on swap execution facilities (SEFs). These venues greatly enhance transparency by automatically disseminating requests for quotes to multiple dealers and by featuring an electronic order book which allows any market participant to compete with dealers for liquidity provision by posting quotes. Thus, SEFs induce competition between existing dealers and also lower the barriers to potential entrants.

Using transactional data from the IRS market we assess the impact of SEF introduction on market activity and liquidity as captured by estimates of the effective spread and the price impact of trades. We find that the move from an OTC to a centralized, competitive market structure is associated with a substantial reduction in execution costs. This is clearest for the USD mandated contracts which are the most strongly affected, given that they are primarily traded by US persons who are captured by the trade mandate. For these contracts, we estimate that the marginal reduction in execution costs relative to EUR mandated contracts amounts to as much as \$3 - \$4 million daily for market end-users.

Additionally, we find that, for the EUR-denominated segment of the market, the bulk of inter-dealer trading previously executed between US and non-US trading desks is now largely being executed by the non-US (mostly European) trading desks of the same institutions. We interpret this as an indication that swap dealers wish to avoid being captured by the trade mandate and the associated SEF impartial access requirements articulated by the CFTC. Migrating the EUR inter-dealer volume off-SEFs enables dealers to choose who to trade with and (more importantly) who not to trade with. Inability to access the inter-dealer market would in turn make it difficult for a potential entrant to compete with incumbent dealers.

While our analysis suggests that so far there has been no incremental negative impact on EUR contract liquidity as a result of this trade fragmentation, it does also imply that it may have negated the liquidity gains experienced in the USD segment of the market. Therefore, given the global nature of OTC derivatives markets, our findings suggest that extending the scope of the trading mandate to cover other sufficiently liquid swap markets would be desirable. This might be especially important given the likely imposition of similar regulation in the EU as part of MiFIR.

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Figure 1: Total traded volume (in $ billion) by currency. In this figure we plot the total volume of EUR-denominated and USD-denominated plain vanilla swaps. The sample covers every spot vanilla interest rate swap which was either cleared by LCH or reported to DTCC between January 1, 2013 and September 15, 2014.

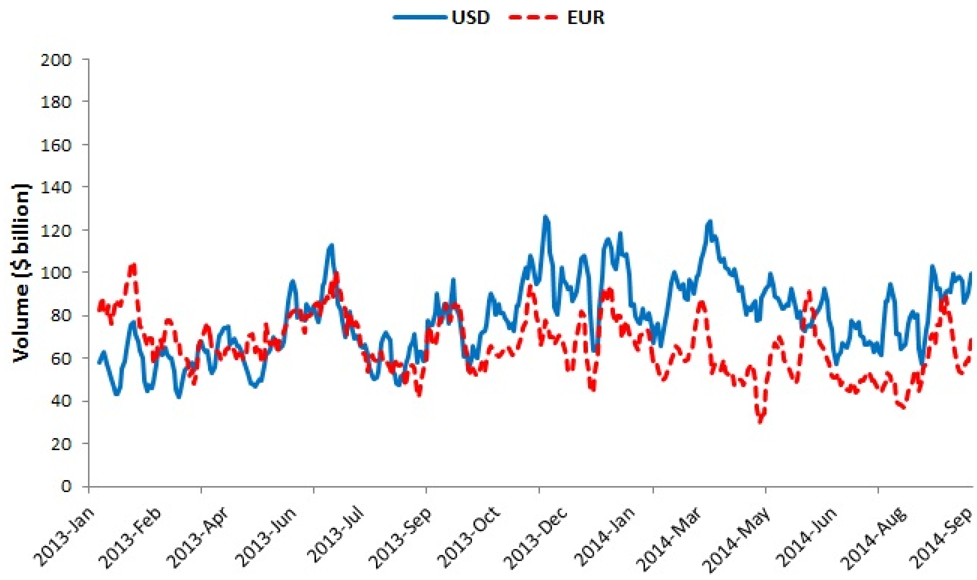

Figure 2: Volume shares by type of counterparty: In this figure we decompose the total volume into dealer-to-dealer (*d2d*), dealer-to-client (*d2c*), and client-to-client (*c2c*) trading. The inner circle presents the volumes of USD-denominated swaps, while the outer circle presents the volumes of EUR-denominated swaps. The sample covers every spot vanilla interest rate swap which was cleared by LCH between January 1, 2013 and September 15, 2014.

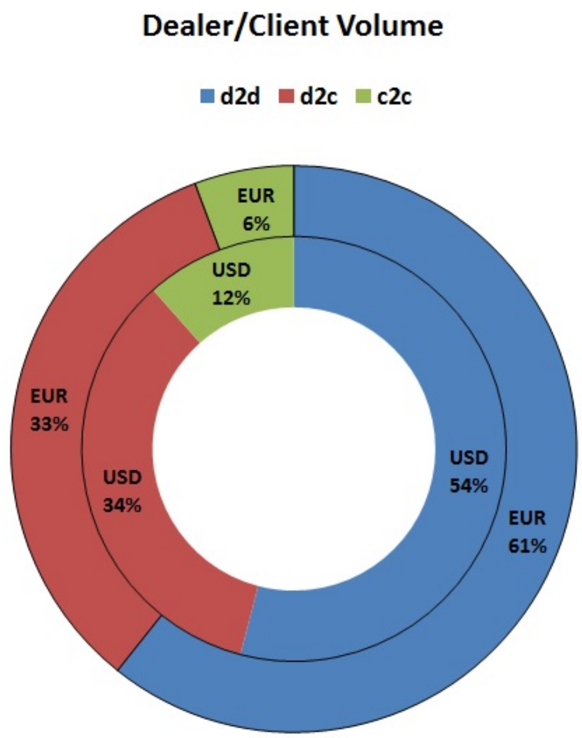

Figure 3: Volume shares by location. In this figure we decompose the total volume into US-to-US, US-to-non-US, and non-US-to-non-US trading. The inner circle presents the volumes of USD-denominated swaps, while the outer circle presents the volumes of EUR-denominated swaps. The sample covers every spot vanilla interest rate swap which was cleared by LCH between January 1, 2013 and September 15, 2014.

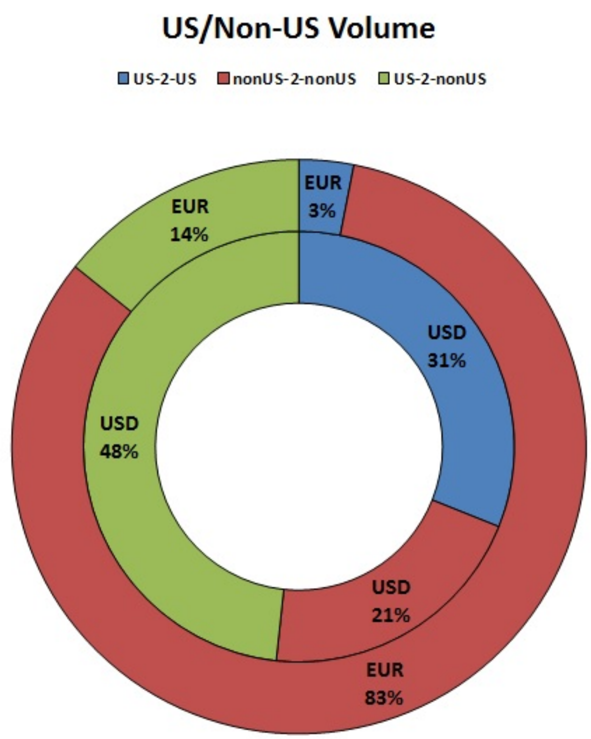

Figure 4: Fraction of SEF trading. In this figure we present the percentage of SEF trading in USD- and EUR-denominated swaps. The sample covers every spot vanilla interest rate swap transaction reported to DTCC. The vertical line marks the introduction of SEFs (October 2, 2013). The time period is January 1, 2013 to September 15, 2014.

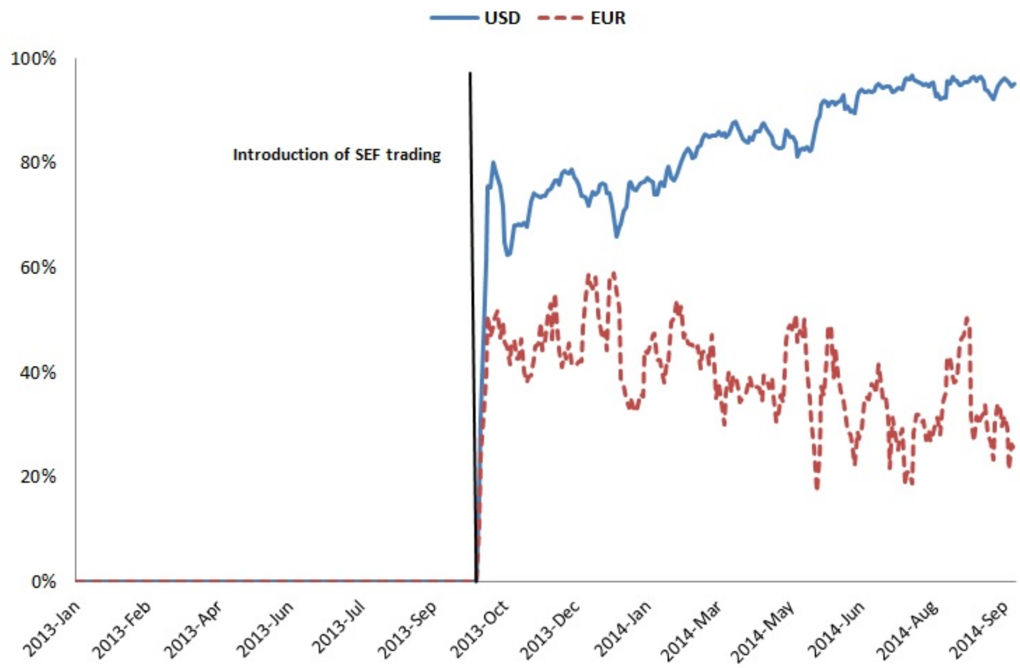

Figure 5: Fraction of US-to-non-US trading. This figure shows the percentage of US-to-non-US trading in USD- and EUR-denominated swaps. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (October 2, 2013). The time period is January 1, 2013 to September 15, 2014.

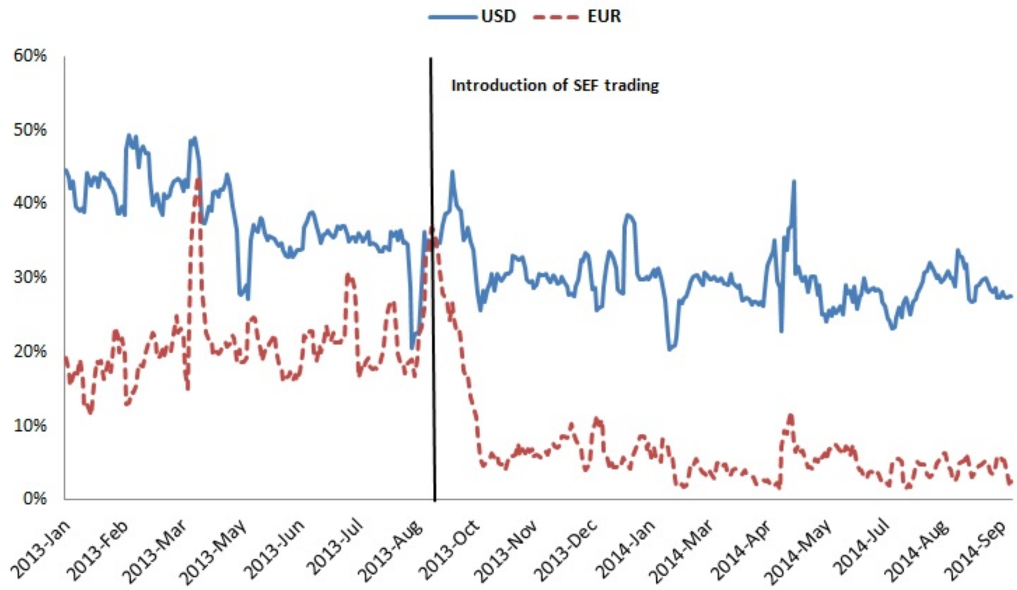

Figure 6: Breakdown of US-to-non-US trading. This figure shows the breakdown of US-to-non-US trading volume in EUR-denominated swaps into inter-dealer volume and all other trading volume. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (October 2, 2013). The time period is January 1, 2013 to September 15, 2014.

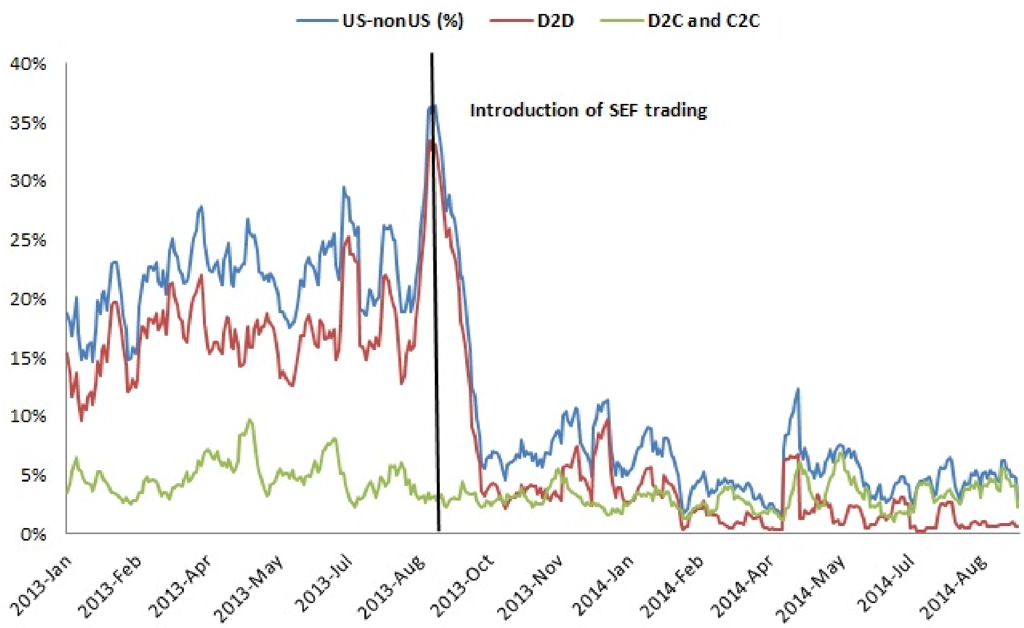

Figure 7: Breakdown of inter-dealer volume by trading desk location. This figure plots the fractions of inter-dealer trading in EUR-denominated swaps executed by US and non-US trading desks, for all swap dealers that have trading desks in the US and at least one more jurisdiction. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (October 2, 2013). The time period is January 1, 2013 to September 15, 2014.

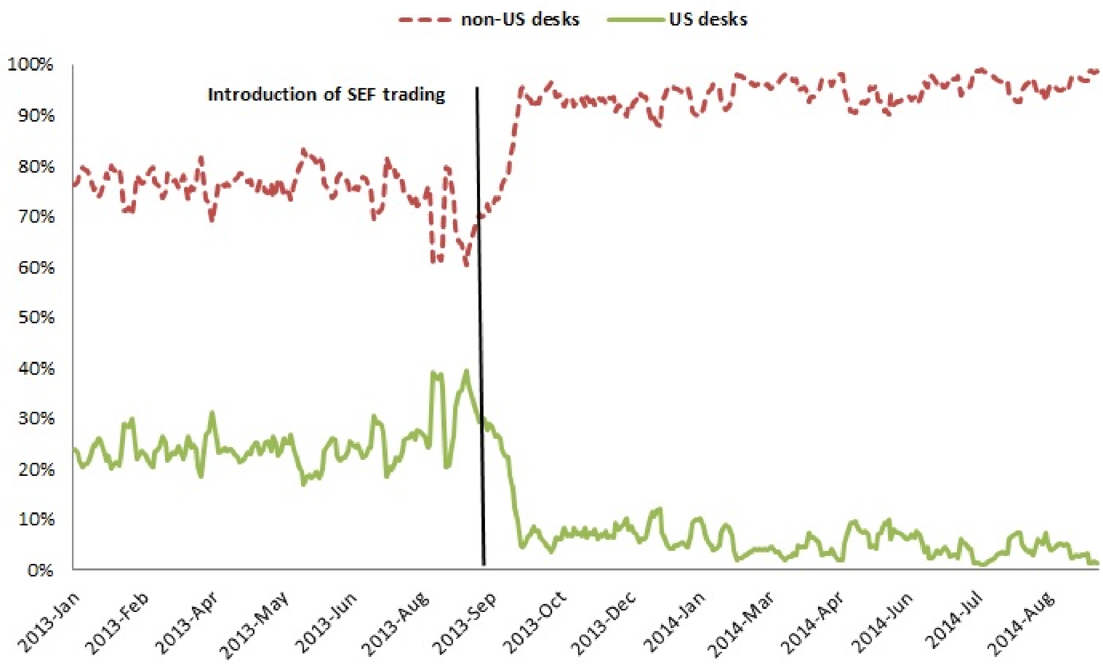

Figure 8: This figure plots the amount of inter-dealer trading in EUR-denominated swaps executed exclusively by swap dealers that have no trading desks in the US. The sample covers every spot vanilla interest rate swap transaction reported to LCH. The vertical line marks the introduction of SEFs (October 2, 2013). The time period is January 1, 2013 to September 15, 2014.

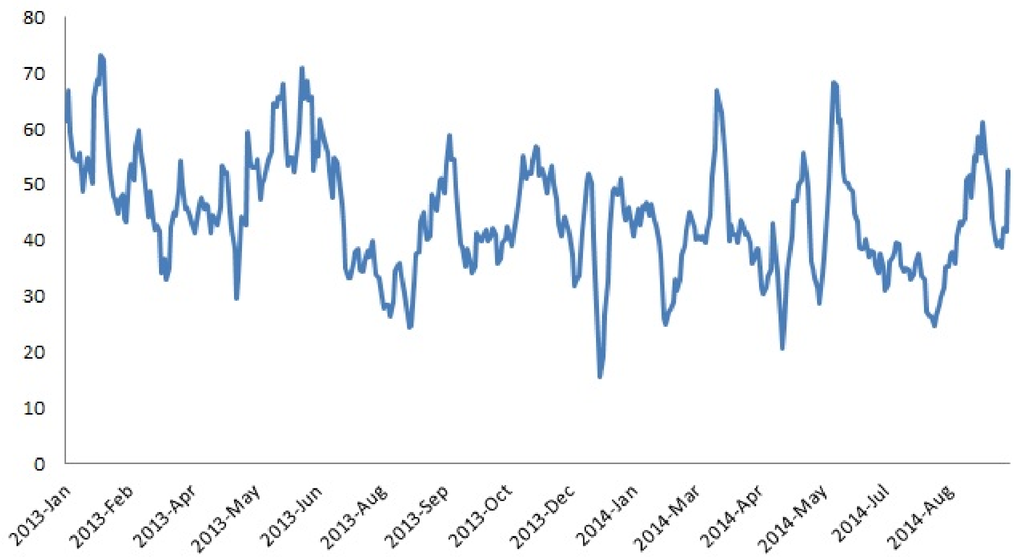

Table 1: SEF trading mandate dates by currency and maturity for plain vanilla IRS contracts used in our study.

Currency	*Maturity*	*Effective date*
USD	2,3,5,7,10,12,15,20,30	15/02/2014
EUR	2,3,5,7,10,12,15,20,30	15/02/2014
USD	4,6	26/02/2014
EUR	4,6	26/02/2014

Table 2: Summary statistics of daily values of the key variables, by currency. The table shows statistics on trading volume (*Vlm*) measured in $ billions; daily number of trades (*Ntrades*); daily unique number of active counterparties (*Nparties*); the fraction of SEF (*SEF*), dealer-to-dealer (*D2D*), and US to non-US (*US-to-non-US*) trading. It also shows statistics on the two dispersion measures and the Amihud price impact measure described in Section 5.1. The data consists of all LCH and DTCC reported transactions for USD- and EUR-denominated plain vanilla swaps. The time period is January 1, 2013 to September 15, 2014.

	USD					EUR				
	Mean	*Sd*	*Min*	*Max*	*N*	*Mean*	*Sd*	*Min*	*Max*	*N*
Activity variables										
Vlm ($ billion)	5.66	7.36	0.02	64.58	5559	4.44	4.49	0.06	44.90	5463
Ntrades	72.88	95.18	4	676	5559	39.82	45.36	4	346	5463
Nparties	22.04	12.25	2	61	5740	19.68	8.59	2	49	5791
Market structure										
SEF (%)	0.48	0.44	0	1	5820	0.20	0.32	0	1	5072
D2D (%)	0.54	0.24	0	1	5740	0.61	0.21	0	1	5791
US-to-non-US (%)	0.48	0.21	0	1	5740	0.14	0.16	0	0.96	5791
Liquidity variables										
Disp (vw)(%)	0.72	0.47	0	4.16	5559	0.67	0.46	0	3.67	5463
Disp (JNS)(%)	0.91	0.58	0.05	4.29	5559	1.16	0.82	0.07	4.60	5463
Amihud	12.92	15.40	0.55	131.13	4813	9.47	7.47	0.98	46.60	4917

Table 3: Panel difference-in-difference specification (fixed effects). We show estimation results of equation (4), where the treatment group are the USD mandated contracts and the control group are the EUR mandated contracts. The dispersion metrics and the Amihud measure are defined in equations (1), (2) and (3) respectively. Vlm is the amount of gross notional traded in US dollars, $Ntrades$ is the number of trades executed and $Nparties$ is the number of unique counterparties active on a given day. $Date^{(1)}$ is a dummy variable that takes the value of 1 after the introduction of SEF trading on 2 October 2013 and $Date^{(2)}$ is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1. $Curr$ is a dummy that takes the value 1 for USD-denominated contracts and is zero otherwise. VIX and $VDAX$ are the S&P 500 and DAX volatility indices and $\log R_{SP500}$ and $\log R_{DAX}$ are the daily log returns on the indices themselves. O/N_Spread_USD and O/N_Spread_EUR are the differences between the overnight unsecured borrowing rates and the respective central bank rates. $Slope\_USD$ and $Slope\_EUR$ are the spreads between the 10-year and 3-month government securities of the US and the investment grade Eurozone countries respectively. The model is estimated using maturity and currency fixed effects. Standard errors are clustered by maturity and currency. Robust t-statistics are shown in the parentheses. *, ** and *** denote significance at 10%, 5% and 1% levels respectively. The time period is January 1, 2013 to September 15, 2014.

	USD mandated vs. EUR mandated											
	Liquidity variables								**Activity variables**			
	Disp (vw)	**Disp (vw)**	**Disp (JNS)**	**Disp (JNS)**	**Amihud**	**Amihud**	**Vlm**	**Vlm**	**Ntrades**	**Ntrades**	**Nparties**	**Nparties**
$Date^{(1)}$	-0.2121***	-0.2907***	-0.3284***	-0.4242***	-2.0951***	-1.6761***	-0.3433**	-0.8100***	-4.2991***	-9.9779***	0.0583	-0.9382**
	(-10.98)	(-8.50)	(-12.44)	(-9.70)	(-5.86)	(-4.14)	(-2.61)	(-4.14)	(-2.91)	(-4.08)	(0.27)	(-2.53)
$Curr \times Date^{(1)}$	0.0162	0.0125	0.0711*	0.0623	0.1214	0.1817	2.4496***	2.4203***	22.4662***	22.1282***	1.4968**	1.4418**
	(0.50)	(0.39)	(1.84)	(1.65)	(0.11)	(0.16)	(3.15)	(3.09)	(3.29)	(3.23)	(2.26)	(2.16)
$Date^{(2)}$	0.1061***	0.0820***	0.2056***	0.1155**	2.2344***	1.4314***	-0.7535**	-0.4165	-6.4935**	-8.7110**	-1.1243***	-1.1673**
	(4.40)	(2.95)	(5.05)	(2.46)	(5.12)	(3.22)	(-2.74)	(-1.21)	(-2.37)	(-2.13)	(-3.06)	(-2.62)
$Curr \times Date^{(2)}$	-0.1345***	-0.1341***	-0.2178***	-0.2127***	-2.0705*	-2.0875*	0.3077	0.3078	4.0289	4.1796	1.1234**	1.1336**
	(-4.85)	(-4.78)	(-4.94)	(-4.83)	(-1.79)	(-1.82)	(0.77)	(0.74)	(1.16)	(1.14)	(2.11)	(2.10)
VIX		0.0259***		0.0247***		0.1335***		0.0524**		0.8681***		0.1319***
		(5.51)		(5.02)		(3.05)		(2.37)		(3.54)		(3.07)
$VDAX$		-0.0075		0.0046		-0.0409		0.0479		0.7111*		0.1234**
		(-1.52)		(1.03)		(-0.93)		(1.45)		(1.77)		(2.64)
$\log R_{SP500}$		-0.7057		-1.6996*		9.2875**		-0.7808		1.2470		8.4060
		(-0.72)		(-1.78)		(2.33)		(-0.16)		(0.03)		(1.02)
$\log R_{DAX}$		0.8911		-3.1542**		2.7264		-6.0868		-130.6328**		-13.2524**
		(1.48)		(-2.59)		(0.78)		(-1.59)		(-2.37)		(-2.11)
O/N_Spread_USD		0.0292		0.6246**		0.2119		-0.7333		-1.2489		-1.2970
		(0.20)		(2.46)		(0.23)		(-0.65)		(-0.12)		(-0.55)
O/N_Spread_EUR		0.3972***		0.6557***		-1.3207**		2.0782***		26.6882***		2.7758***
		(6.06)		(5.74)		(-2.35)		(3.65)		(3.40)		(3.05)
$Slope\_USD$		-0.1404***		-0.1767***		0.2386		-0.5688		-4.2657		0.4030
		(-4.22)		(-3.59)		(0.40)		(-1.26)		(-1.10)		(0.53)
$Slope\_EUR$		0.0179		-0.0036		-2.4992***		1.4243***		3.8056		0.5573
		(0.36)		(-0.05)		(-2.99)		(3.24)		(0.72)		(0.61)
$Constant$	0.8362***	1.0589***	1.2040***	1.5129***	9.2612***	11.5093***	5.6516***	3.7868***	64.8541***	57.3357***	23.0793***	18.8475***
	(91.65)	(8.55)	(107.22)	(9.68)	(43.55)	(7.40)	(25.80)	(2.85)	(30.44)	(4.77)	(100.95)	(13.31)
$Within\text{-}R^2$	0.054	0.070	0.040	0.060	0.115	0.142	0.042	0.052	0.033	0.047	0.013	0.029
N	8821	8740	8821	8740	7843	7783	8821	8740	8821	8740	8821	8740

Table 4: Panel difference-in-difference specification (fixed effects). We show estimation results of specification (5), where the treatment group consists of the USD mandated contracts and the control group of the USD non-mandated contracts. The dispersion metrics and the Amihud measure are defined in equations (1), (2) and (3) respectively. Vlm is the amount of gross notional traded in US dollars, $Ntrades$ is the number of trades executed and $Nparties$ is the number of unique counterparties active on a given day. $Date^{(1)}$ is a dummy variable that takes the value of 1 after the introduction of SEF trading on 2 October 2013 and $Date^{(2)}$ is a dummy variable that takes the value of 1 after the mandate effective dates as per Table 1. MAT is a dummy that takes the value 1 for mandated contracts and is zero otherwise. VIX is the S&P 500 volatility index and $\log R_{SP500}$ is the log daily return on the index itself. *O/N_Spread_USD* is the difference between the overnight unsecured borrowing rate and the respective central bank rate. *Slope_USD* is the spreads between the 10-year and 3-month Treasury securities. The model is estimated using maturity fixed effects. Standard errors are clustered by maturity. Robust t-statistics are shown in the parentheses. *, ** and *** denote significance at 10%, 5% and 1% levels respectively. The time period is January 1, 2013 to September 15, 2014.

	USD mandated vs. USD non-mandated											
	Liquidity variables								Activity variables			
	Disp (vw)	Disp (vw)	Disp (JNS)	Disp (JNS)	Amihud	Amihud	Vlm	Vlm	Ntrades	Ntrades	Nparties	Nparties
$Date^{(1)}$	-0.2220***	-0.2301***	-0.3372***	-0.3288***	-10.7954**	-9.9152**	0.1963	-0.4108	0.5327	-5.2531**	-0.5161***	-1.8809***
	(-3.87)	(-4.25)	(-6.37)	(-6.05)	(-2.24)	(-2.27)	(1.64)	(-1.66)	(1.24)	(-2.36)	(-3.91)	(-5.79)
$MAT \times Date^{(1)}$	0.0261	0.0227	0.0799	0.0780	8.8217*	8.7920*	1.9100**	1.8953**	17.6343**	17.3370**	2.0712***	2.0432***
	(0.41)	(0.36)	(1.33)	(1.32)	(1.79)	(1.80)	(2.43)	(2.43)	(2.61)	(2.59)	(3.20)	(3.16)
$Date^{(2)}$	0.0304	0.0605***	0.0582**	0.0865***	3.7241*	3.5274**	-0.0645	0.2702	0.2127	3.5493**	-0.1081	0.4925*
	(1.73)	(3.19)	(2.18)	(3.02)	(1.94)	(2.19)	(-0.30)	(1.13)	(0.41)	(2.76)	(-0.45)	(2.03)
$MAT \times Date^{(2)}$	-0.0589**	-0.0576**	-0.0704**	-0.0690**	-3.5602	-3.5700	-0.3813	-0.3731	-2.6773	-2.5792	0.1072	0.1226
	(-2.63)	(-2.62)	(-2.23)	(-2.21)	(-1.62)	(-1.63)	(-1.05)	(-1.03)	(-1.20)	(-1.16)	(0.23)	(0.27)
VIX		0.0278***		0.0333***		0.1261		0.1396***		1.8043**		0.2253***
		(6.17)		(6.23)		(0.76)		(3.16)		(2.82)		(6.08)
$\log R_{SP500}$		-2.8813***		-3.2104***		4.7511		-11.1654**		-149.5849		-18.8083**
		(-4.77)		(-4.42)		(0.30)		(-2.29)		(-1.75)		(-2.19)
O/N_Spread_USD		-0.1680		-0.3533		-6.1576		1.0264		-16.8542		-1.3618
		(-0.98)		(-1.68)		(-0.95)		(0.77)		(-1.11)		(-0.55)
Slope_USD		-0.0085		-0.0578		-2.1722		1.1075**		8.7058**		2.2894***
		(-0.28)		(-1.43)		(-1.43)		(2.69)		(2.19)		(3.92)
Constant	0.8441***	0.4681***	1.0916***	0.7406***	15.1952***	17.9719***	4.6513***	0.3715	62.1412***	18.3383	20.9446***	12.9701***
	(65.67)	(3.94)	(69.89)	(5.06)	(24.26)	(3.26)	(14.97)	(0.22)	(20.93)	(1.04)	(62.82)	(7.67)
Within-R^2	0.065	0.088	0.065	0.084	0.137	0.146	0.049	0.062	0.031	0.044	0.013	0.032
N	5875	5861	5875	5861	5090	5090	5875	5861	5875	5861	5875	5861

Table 5: SEF trading panel regressions. We show the estimation results of specification (6) for USD and EUR-denominated mandated contracts. The dispersion metrics and the Amihud measure are defined in equations (1), (2) and (3) respectively. Vlm is the amount of gross notional traded in US dollars, $Ntrades$ is the number of trades executed and $Nparties$ is the number of unique counterparties active on a given day. SEF is the percent of the total trading volume executed on a SEF, $Date^{(1)}$ is a dummy variable that takes the value of 1 after the introduction of SEF trading (2 October 2013), VIX and $VDAX$ are the S&P 500 and DAX volatility indices and $\log R_{SP500}$ and $\log R_{DAX}$ are the daily log returns on the indices themselves. O/N_Spread_USD and O/N_Spread_EUR are the differences between the overnight unsecured borrowing rates and the respective central bank rates. $Slope\_USD$ and $Slope\_EUR$ are the spreads between the 10-year and 3-month government securities of the US and the investment grade Eurozone countries respectively. The model is estimated using maturity and currency fixed effects. The top panel shows the results of fixed effects specifications and the bottom panel shows the results of instrumental variable fixed effects specifications where SEF is treated as endogenous and is instrumented using own lags. Standard errors are clustered by maturity and currency. Robust t-statistics are shown in the parentheses. *, ** and *** denote significance at 10%, 5% and 1% levels respectively. The time period is January 1, 2013 to September 15, 2014.

	Disp (vw)	**Disp (JNS)**	**Amihud**	**Vlm**	**Ntrades**	**Nparties**	**Disp (vw)**	**Disp (JNS)**	**Amihud**	**Vlm**	**Ntrades**	**Nparties**
SEF	-0.1187***	-0.1195***	-1.1838***	1.3734**	15.5799**	1.6590**	-0.3077***	-0.3910***	-3.6329***	4.0384***	42.0938***	2.4658***
	(-4.21)	(-2.97)	(-3.12)	(2.62)	(2.69)	(2.74)	(-5.39)	(-4.40)	(-8.89)	(7.56)	(7.63)	(3.02)
$Date^{(1)}$	-0.2132***	-0.3188***	-0.7600*	-0.4560**	-9.5808***	-1.3354***	-0.0857**	-0.1467**	0.5922**	-2.0579***	-25.7008***	-1.8113***
	(-5.86)	(-6.27)	(-1.90)	(-2.21)	(-2.95)	(-3.94)	(-2.19)	(-2.41)	(2.20)	(-5.61)	(-6.78)	(-3.23)
$\log R_{SP500}$	-0.9784	-2.1289**	7.1627	-2.9168	-6.8581	3.7181	-2.3924***	-4.2694***	9.1158	-10.8112	-86.4967	-2.6194
	(-1.05)	(-2.29)	(1.54)	(-0.63)	(-0.14)	(0.55)	(-2.74)	(-3.14)	(1.53)	(-1.32)	(-1.02)	(-0.21)
$\log R_{DAX}$	1.1575*	-2.4488**	2.7685	-4.8869	-119.9649**	-11.1949	1.5829**	-1.6626*	0.7966	-2.8460	-97.0765	-9.0646
	(1.87)	(-2.15)	(0.77)	(-1.13)	(-2.18)	(-1.65)	(2.57)	(-1.73)	(0.19)	(-0.49)	(-1.63)	(-1.03)
VIX	0.0242***	0.0219***	0.1017*	0.0541*	1.0927***	0.1261**	0.0223***	0.0198***	0.1155***	0.0553	1.0494**	0.1094*
	(5.42)	(4.03)	(1.78)	(1.97)	(2.99)	(2.74)	(4.98)	(2.84)	(3.76)	(1.32)	(2.42)	(1.70)
VDAX	-0.0059	0.0067	-0.0030	0.0404	0.4552	0.1144**	-0.0037	0.0079	-0.0089	0.0240	0.2630	0.1345**
	(-1.29)	(1.54)	(-0.04)	(1.32)	(1.27)	(2.44)	(-0.83)	(1.15)	(-0.29)	(0.58)	(0.61)	(2.12)
O/N_Spread_USD	0.0381	0.5575**	0.1891	-0.7651	-3.9332	-1.1245	0.2317	0.7659***	1.8161	0.2081	1.1789	0.7409
	(0.25)	(2.42)	(0.19)	(-0.63)	(-0.36)	(-0.47)	(1.23)	(2.62)	(1.36)	(0.12)	(0.06)	(0.28)
O/N_Spread_EUR	0.4167***	0.6491***	-1.1741*	2.1614***	26.9385***	2.7742***	0.4091***	0.6459***	-0.7670**	2.5476***	32.0757***	2.8789***
	(6.53)	(6.04)	(-2.08)	(3.85)	(3.74)	(3.35)	(7.51)	(7.62)	(-2.17)	(4.99)	(6.09)	(3.70)
Slope_USD	-0.1398***	-0.1727***	0.3501	-0.6945	-6.9338	0.2689	-0.1181***	-0.1373***	0.4462**	-0.8365***	-9.5411***	0.4588
	(-4.51)	(-3.56)	(0.55)	(-1.41)	(-1.70)	(0.35)	(-3.94)	(-2.94)	(2.23)	(-2.98)	(-3.29)	(1.07)
Slope_EUR	-0.0022	-0.0214	-2.8336**	1.8431***	13.2542***	1.1587	-0.0069	-0.0451	-3.0147***	2.3471***	19.3226***	1.2136**
	(-0.05)	(-0.30)	(-2.63)	(3.78)	(2.97)	(1.40)	(-0.21)	(-0.88)	(-13.95)	(7.61)	(6.06)	(2.58)
Constant	1.1132***	1.5407***	11.6262***	3.5852**	48.6817***	18.6906***	1.0700***	1.5178***	11.6580***	3.5571***	51.6001***	18.6155***
	(8.89)	(9.60)	(8.11)	(2.67)	(4.19)	(16.11)	(13.55)	(12.35)	(21.74)	(4.81)	(6.76)	(16.49)
R^2	0.070	0.058	0.116	0.026	0.027	0.022	0.060	0.050	0.078	0.008	0.011	0.022
N	8316	8316	7387	8316	8316	8316	7535	7535	6714	7535	7535	7535
Specification	FE	FE	FE	FE	FE	FE	FE & IV	FE & IV	FE & IV	FE & IV	FE & IV	FE & IV

Table 6: Time series regressions of the percentage of US-to-non-US volume in the USD and EUR-denominated contracts in our sample. $Date^{(1)}$ is a time dummy that takes the value 1 after the introduction of SEF trading on 2 October 2013, $\log R_{SP500}$ and $\log R_{DAX}$ are the daily log returns of the S&P 500 and DAX indices and VIX and $VDAX$ are estimates of the implied volatility of these indices. *O/N_Spread_USD* and *O/N_Spread_EUR* are the differences between the overnight unsecured borrowing rates and the respective central bank rates. *Slope_USD* and *Slope_EUR* are the spreads between the 10-year and 3-month government securities of the US and the investment grade Eurozone countries respectively. Robust t-statistics are shown in the parentheses. *, ** and *** denote significance at 10%, 5% and 1% levels respectively. The time period is January 1, 2013 to September 15, 2014.

	US-to-non-US (USD)	**US-to-non-US (EUR)**
$Date^{(1)}$	0.0137	-0.1608***
	(0.96)	(-10.76)
$\log R_{SP500}$	-0.0634	0.2010
	(-0.10)	(0.34)
$\log R_{DAX}$	-0.0156	-0.1819
	(-0.03)	(-0.47)
VIX	0.0022	-0.0011
	(0.72)	(-0.40)
VDAX	0.0017	0.0016
	(0.61)	(0.56)
O/N_Spread_USD	0.1256	-0.1888
	(0.80)	(-1.22)
O/N_Spread_EUR	-0.0831*	-0.0619*
	(-1.90)	(-1.68)
Slope_USD	0.0095	0.0162
	(0.38)	(0.62)
Slope_EUR	0.0001	0.0306
	(0.00)	(1.59)
Constant	0.3748***	0.0981*
	(6.30)	(1.77)
R^2	0.089	0.734
N	307	307

Table 7: Fragmentation panel regressions. We show the estimation results of specification (7) for EUR-denominated contracts. The dispersion metrics and the Amihud measure are defined in equations (1), (2) and (3) respectively. Vlm is the amount of gross notional traded in US dollars, $Ntrades$ is the number of trades executed and $Nparties$ is the number of unique counterparties active on a given day. *fragm* is one minus the percentage of volume traded between US and non-US counterparties, $Date^{(1)}$ is a time dummy that takes the value 1 after the introduction of SEF trading on 2 October 2013, $\log R_{SP500}$ and $\log R_{DAX}$ are the daily log returns of the S&P 500 and DAX indices and *VIX* and *VDAX* are estimates of the implied volatility of these indices. *O/N_Spread_USD* and *O/N_Spread_EUR* are the differences between the overnight unsecured borrowing rates and the respective central bank rates. *Slope_USD* and *Slope_EUR* are the spreads between the 10-year and 3-month government securities of the US and the investment grade Eurozone countries respectively. The model is estimated using maturity fixed effects. Standard errors are clustered by maturity. Robust t-statistics are shown in the parentheses. *, ** and *** denote significance at 10%, 5% and 1% levels respectively. The time period is January 1, 2013 to September 15, 2014.

	Disp (vw)	**Disp (JNS)**	**Amihud**	**Vlm**	**Ntrades**	**Nparties**
fragm	-0.5964	-0.4729	0.1609	-2.0472***	-3.2927**	-1.3109**
	(-0.90)	(-0.81)	(0.39)	(-4.69)	(-2.97)	(-2.63)
$Date^{(1)}$	-0.3866***	-0.8235*	-2.0481***	0.0016	-3.3319**	0.2955
	(-3.94)	(-2.14)	(-5.56)	(0.01)	(-2.95)	(1.05)
$\log R_{SP500}$	-3.9949	0.4508	10.0129*	6.8007	107.6561***	27.0525***
	(-0.60)	(0.35)	(2.09)	(1.38)	(3.33)	(3.10)
$\log R_{DAX}$	-9.8511	-19.2031	3.9104	-2.3227	-56.2627	-7.5684
	(-1.06)	(-1.70)	(1.19)	(-0.54)	(-1.43)	(-1.01)
VIX	0.1112	0.1714	0.0911	0.0666**	0.8843***	0.1538***
	(1.27)	(1.13)	(1.52)	(2.53)	(3.11)	(3.24)
VDAX	-0.1058	-0.1859	0.0257	-0.0369*	-0.3495	0.0391
	(-1.21)	(-1.00)	(0.40)	(-2.04)	(-1.62)	(0.68)
O/N_Spread_USD	0.4546	3.2035	0.0971	-3.2532***	-24.0778***	-6.5624**
	(0.90)	(1.67)	(0.08)	(-3.39)	(-3.07)	(-2.76)
O/N_Spread_EUR	0.3861***	0.7816***	-0.2917	1.7321**	10.4110	1.7546
	(3.30)	(3.65)	(-0.68)	(2.51)	(1.76)	(1.05)
Slope_USD	-0.4361	-0.1518	0.9323	-1.3911**	-10.0635*	-1.6763**
	(-1.15)	(-1.61)	(1.02)	(-2.34)	(-2.06)	(-2.35)
Slope_EUR	1.5835	1.8480	0.1223	1.3761**	7.7884	1.2913
	(1.23)	(1.56)	(0.11)	(2.47)	(1.73)	(1.00)
Constant	2.7965**	8.1578*	15.2246***	6.3808***	42.0813***	17.7457***
	(2.15)	(1.91)	(6.09)	(8.77)	(14.51)	(22.58)
R^2	0.003	0.010	0.215	0.036	0.041	0.024
N	5749	5749	5178	5749	5749	5749